MONITORING OF R-2000 LOW ENERGY HOMES 1987

Annual Report

Ontario

MONITORING OF R-2000 LOW ENERGY HOUSES 1987 ANNUAL REPORT

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MONITORING OF R-2000 LOW ENERGY HOUSES

ONTARIO MINISTRY OF ENERGY

SUMMARY OF THE JUNE, 1987 REPORT

This is the second Annual Report in the Ministry of Energy's R-2000 Monitoring Project.

R-2000 is a recognized standard for practical, low energy new housing in Canada. Emphasis is placed on insulation, air tightness, controlled ventilation and heat recovery from exhaust air.

The R-2000 Home Program is a co-operative government/industry initiative which began in 1982. It is funded by the Federal Department of Energy, Mines and Resources (EMR) and is administered across Canada by the provincial offices of the Canadian Home Builders' Association (CHBA).

Since September, 1985, twenty two R-2000 low energy houses have been monitored, in detail, by the Ministry of Energy, in four locations in Ontario (Sudbury, Kingston, Fonthill, and Erin Mills). The monitoring has concentrated on energy performance, air quality, construction reliability, comfort levels and owner satisfaction.

A skilled monitoring contractor visits each house monthly. The contractor records energy readings, changes air quality samplers, performs tests and inspections, and interviews the house occupants. Four of the R-2000 houses are instrumented with PC-based data acquisition systems, which monitor energy and ventilation variables.

The monitoring project was designed to determine the following information about R-2000 houses:

How much energy does an R-2000 house use?

Do R-2000 houses, with their low air leakage rates, have acceptable air quality?

Do R-2000 builders produce reliable, durable homes, free from moisture problems?

Do R-2000 builders produce houses which are comfortable, in all weather conditions?

Are R-2000 owners satisfied with their houses?

Monitoring Results

Results from two years of monitoring are as follows:

Energy

The space heating requirements of R-2000 houses are much less than the requirements for typical new non-R-2000 houses in Ontario (typically about 130 kWh per year per square meter of floor area). Results from the monitoring show that space heating energy consumption for R-2000 houses is less than 40% of the consumption for typical non-R-2000 new houses in Ontario.

The second year results show that the monitored performance for 86/87 was considerably better than for 85/86. The improvement was caused by air sealing retrofits at some of the houses by homeowners and builders.

Most of the 22, R-2000 houses were close to the R-2000 program target for space heating energy consumption.

Air Quality

R-2000 houses have good air quality.

No hazardous levels of radon, carbon monoxide, or carbon dioxide were detected in any of the monitored R-2000 houses, during the year.

The contractor did measure levels of formaldehyde which were higher than recognized standards, in many of the houses, during humid summer weather. This high summer formaldehyde concentration has been observed in non-R-2000 houses as well. The contractor's discovery of the annual cycle of formaldehyde concentrations raises some concerns about established exposure standards and short-term measurement techniques.

During the second year, none of the homeowners complained about air quality problems, other than statistically normal complaints about the presence or absence of humidity. The previous year's complaints about dust ended when the builders completed construction and landscaping.

Construction Reliability

After two years, all of the R-2000 houses are solid, with no moisture in the walls or ceilings, and no cracks in the walls, ceilings, or structure.

Comfort Levels

Continuous hour-by-hour analysis of temperatures, humidities, and furnace cycles in four houses showed that all rooms were comfortable in all winter weather conditions. The maximum temperature difference between cool ventilation air and room air was only 3°C.

On the coldest winter days, the supply of heat in all houses was enough to maintain comfort during the entire winter. Thus, the previous year's complaints about cold rooms by some homeowners appear to be caused by distribution problems, not by supply problems.

Owner Satisfaction

After two years of ownership, the majority of the occupants remain satisfied with their R-2000 houses.

The degree of owner satisfaction depends strongly on the location and builder. The cost of energy, relative to the total housing budget, is also important. In general, R-2000 houses are attractive to homebuyers because of lower energy costs and greater comfort.

During the monitored year, 35% of the houses were sold to new owners.

Budget

The total budget for the second year of the monitoring project was $190,000 (Cdn). The total, two-year budget was $430,000 (Cdn).

Future Plans

The Ministry intends to continue with the R-2000 Monitoring Project, until June, 1988.

Five more R-2000 houses, completed in February, 1987, have been added to the monitoring project. These new houses will demonstrate the effect of changes in R-2000 construction techniques by the builder.

In a separate project, another contractor is improving the ventilation systems in some of the R-2000 houses. The third year's monitored data will show the effect of the remedial measures on ventilation rates, air quality, and energy use.

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1.0 INTRODUCTION

Buchan, Lawton, Parent Ltd., under contract with the Ontario Ministry of Energy, is undertaking an investigation of R-2000 houses built under the Ministry's Affordable Low Energy New Housing Program.

The monitoring program is intended to investigate four specific areas. These areas are:

- the energy performance of the houses,
- the quality of the internal environment,
- the level of homeowner satisfaction, and
- construction reliability.

This report details the work undertaken and the results obtained during the first twenty two months of the monitoring program commencing in September 1985 and ending June 30, 1987. This report concentrates on results from May 1, 1986 to June 30, 1987. A detailed discussion of the results obtained during the initial program period and a complete description of the houses being monitored is included in the 1986 monitoring report.

1.1 Description of the Monitoring Program

The monitoring program involves twenty seven R-2000 houses. Fifteen of these were built under the Ministry's Affordable Low Energy New Housing Program in 1983 and 1984 in three communities: Sudbury, Kingston, and Fonthill.

The remaining twelve R-2000 houses are part of a two phase townhouse development project in Erin Mills (Mississauga). The first phase of the project included 82 units and the second phase included 120. Seven units in Phase I have been monitored since September 1985 and five units in Phase II were added in February 1987.

These four communities were chosen in order that the monitoring span the range of climatic conditions experienced by R-2000 homes built under the programs.

The inspection and certification of the R-2000 houses built under the Affordable Low Energy New Housing Program was undertaken by the Canadian Home Builders' Association on behalf of the Ministry. The inspection and certification of the Erin Mills houses was undertaken by the Ontario Home Builders' Association on the behalf of Energy, Mines and Resources Canada.

As well as the twenty seven R-2000 homes involved in the monitoring program, there are five control homes from which background data is also gathered. All twenty seven R-2000 houses included in the monitoring program have been extensively tested to characterize each individual house. The details of the test program are included in Section 2.0 of this report.

Energy data is gathered from each house in order to generate energy use profiles on a month by month basis which can be compared with HOTCAN computer predictions for each house. Submetering data is collected in order to individually measure energy for space heating and energy for domestic hot water production. The results of the energy analysis program are detailed in Section 3.0 of this report.

The monitoring of the indoor environment in each house consists of the measurement of the concentrations of four specific indoor pollutants:

- formaldehyde,
- radon,
- carbon dioxide, and
- carbon monoxide.

The results of the indoor air quality analysis portion of the monitoring program are discussed in Section 4.0 of this report.

One house in each of the communities where monitoring is being undertaken was selected for detailed monitoring with the use of a computerized data acquisition system. The computerized data acquisition systems are designed to continuously monitor and record temperatures and humidities throughout the house as well as the operation and the status of major mechanical systems in each house.

The detailed monitoring portion of the program particularly emphasizes the performance monitoring of the heat recovery ventilator (HRV) system. The results of the detailed monitoring program are discussed in Section 5.0 of this report.

Through the use of homeowner interviews, detailed questionnaires were filled out to produce profiles of the occupants in the houses being monitored and to provide a mechanism for the feedback of homeowner concerns and comments about the performance of their house. Additional information as to homeowner concerns is continually gathered through ongoing contact with each homeowner. The results of this portion of the monitoring program are discussed in Section 6.0 of this report.

The monitoring program involves monthly visits to each house by Buchan, Lawton, Parent Ltd. personnel. At that time, energy data is collected, air quality samplers are deployed and specific tests of the house are undertaken. The specific house testing carried out during each monthly visit varies throughout the monitoring program based on a pre-determined schedule designed to have specific tests carried out under the most appropriate climatic conditions.

A profile of each R-2000 house in the monitoring program is included as Appendix A of this report. The profiles include a basic description of the house and its mechanical systems, a profile of the occupants of the house, and specific monitoring data. The profiles have been updated to reflect the situation as of May 1987.

2.0 HOUSE TESTING

Extensive testing of the twenty seven R-2000 houses being studied in this project has been carried out. The major tests performed included:

- fan depressurization testing,
- thermographic scanning,
- combustion appliance backdraft testing,
- sound level testing,
- ventilation capacity testing, and
- combustion appliance efficiency testing.

These tests are carried out on an annual basis.

2.1 Depressurization Testing

The twenty seven R-2000 houses were tested using the CGSB Standard CAN2 149.10 M87, to determine the air leakage characteristics of the building envelope. Table 2.1.1 presents the results of the testing in terms of air changes per hour at a 50 pascal pressure difference across the building envelope. This table presents the results of the original certification tests carried out by a variety of different air tightness testing contractors, the tests performed during the first year of monitoring and the tests performed during the second year of monitoring. The first and second year monitoring tests were performed in an identical fashion with the same equipment. The test apparatus used was a Retrotec door fan model RD501.

As can be seen from the table, in some cases there are significant differences between the results of the original certification tests and the first tests carried out for monitoring purposes. In all cases the monitoring tests show increased levels of air leakage. Whether the differences are due to changes in the envelope characteristics, differences in test equipment or differences in test methodology cannot be determined conclusively. A review of the original certification test reports did not reveal any significant concerns with those tests.

A comparison of the results of the first year monitoring depressurization test and the results from the second year of monitoring show a much better correlation. In some cases, the air leakage rates have decreased. The improvements are generally attributable to remedial work carried out by the builders and/or homeowners.

In the case of the Erin Mills Phase II units, a retest of one unit was undertaken after the Buchan, Lawton, Parent Ltd. monitoring test to determine if a calibration problem existed between the fan used for certification and the Buchan, Lawton, Parent Ltd. fan. The retesting by the

TABLE 2.1.1 **DEPRESSURIZATION TEST RESULTS**
Changes Since Original Post-Construction Depressurization
Test Stated in terms of Air Changes per Hour at 50 Pa

	House Volume (m3)	Original Test Results (ACH)	1985 BLP Test Results (ACH)	1986 BLP Test Results (ACH)
SUDBURY				
House A	495	0.62	1.34	1.45
House B	450	0.52	0.88	1.11
House C	492	0.97	1.12	-
House D	485	0.82	1.25	1.11
House E	494	0.97	1.53	1.54
	Average (excluding C)	0.73	1.25	1.30
KINGSTON				
House A	682	1.37	1.51	1.47
House B	621	1.22	1.34	1.36
House C	647	1.34	1.78	-
House D	521	1.30	1.42	1.39
House E	682	1.03	1.24	1.26
	Average (excluding C)	1.23	1.38	1.37
FONTHILL				
House A	696	1.22	1.88	2.09
House B	518	1.41	2.37	2.52
House C	580	1.44	1.71	1.73
House D	679	1.46	1.70	1.66
House E	573	1.48	1.89	1.72
	Average	1.40	1.91	1.94
ERIN MILLS Phase I				
House A	522	1.45	2.64	2.17
House B	527	1.53	2.65	2.37
House C	527	1.51	2.62	2.99
House D	522	1.48	2.18	2.01
House E	574	1.44	1.81	2.00
House F	479	1.45	1.80	1.82
House G	479	1.47	1.84	2.47 *
	Average (excluding G)	1.48	2.28	2.23
ERIN MILLS Phase II				
House H	574	1.29	-	1.78
House I	479	1.40	-	1.97
House J	479	0.85	-	1.35
House K	527	1.08	-	1.49
House L	527	1.36	-	1.86
	Average	1.20	-	1.69

NOTE: * one window frozen slightly open

certifying agent produced essentially identical results to the Buchan, Lawton, Parent Ltd. test. The fan test apparatus used by the certification agent at Erin Mills was also a Retrotec RD501.

A graphical presentation of the results of the air leakage tests undertaken in the second year of monitoring is included as Figure 2.1.1.

2.2 Thermographic Testing

A thermographic scanning of the building envelope provides a useful method of determining areas of heat loss due to conduction and areas where substantial air leakage is occurring.

Complete thermographic scans were undertaken on two separate occasions between November 1986 and February 1987.

During the November 1986 testing, the houses were examined for thermal bridging and other heat loss areas with an Inframetrics Model 522 colour thermographic camera. A similar thermographic survey was undertaken in November 1985 and the results of the examination are included in the 1986 report. To provide consistent results between the two reports, houses were scanned while under a depressurization of 30 Pa. While in the houses, a permanent record of significant leakage areas was made by taking Polaroid pictures of the image produced by the camera.

Typical air leakage areas in the houses were consistent between the two years and included:

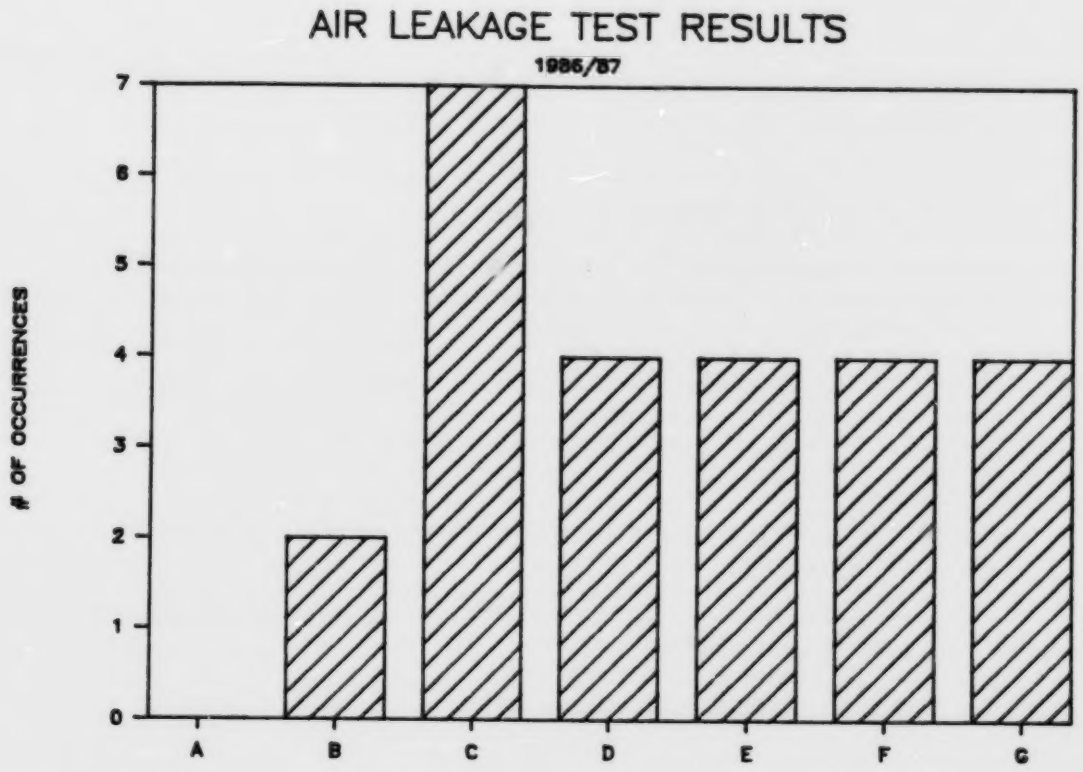
- wall penetrations for such purposes as electrical service entries etc.,
- sliding glass doors,
- sliding windows,
- fresh air inlets of fireplaces, and
- floor header areas.

During retesting in February 1987, the houses were examined while they were operating under normal pressure conditions. The thermographic scans were used to spot significant areas of thermal bridging and, of particular interest, condensation problems. The results were again consistent with the previous years results in that no significant problems with moisture accumulation in the building structure were noted.

2.3 Backdraft Testing

The standard R-2000 test for backdrafting of combustion appliances as outlined in the R-2000 Guidelines and Procedures Manual Section 11 was used in all houses with non-induced draft furnaces or with fireplaces in the first year of the monitoring program. In the second year of the program backdraft testing was redone using a hot flue method.

In the hot flue method, the flue is pre-heated with a propane heater. The heat source is left in the appliance during the test. The house is



LEGEND

A less than 1.00 air changes per hour (ACH) at 50 Pa.
B between 1.00 and 1.24 ACH at 50 Pa.
C between 1.25 and 1.49 ACH at 50 Pa.
D between 1.50 and 1.74 ACH at 50 Pa.
E between 1.75 and 1.99 ACH at 50 Pa.
F between 2.00 and 2.24 ACH at 50 Pa.
G greater than 2.25 ACH at 50 Pa.

Figure 2.1.1

depressurized until the distortion of the flame and smoke pencil testing around the doors indicate backdrafting is occurring. This pressure is recorded and is presented as a summary of the hot flue backdraft test results in Table 2.3.1.

As can be seen from the chart, some of the fireplaces could be made to backdraft at pressures below the current R-2000 Program maximum allowable continuous negative house pressure of 10 Pa and all fireplaces backdrafted at or below the maximum allowable intermittent house pressure of 20 Pa.

It should be noted that the heat generation rate of the burner used during the hot flue test would be much less than that of a wood fire but the heat generation rate of the burner would be more than that of a smoldering fire.

2.4 Sound Level Testing

For sound level testing, two integrating A-weighted (B&K Model 2225) sound level meters were used. A technician operated one meter at a position 2.5 metres from an outside wall at the front of the house, while another technician measured sound levels within the house. Sixty second equivalent average noise levels were taken. The results are presented in Table 2.4.1.

Generally, when moderate noise levels were present at the exterior of the building (e.g., 50 to 60 dBA) a 10 to 20 dBA difference was noted between the interior and exterior sound levels. When moderate noise levels were present at the exterior of a non-R-2000 building (eg., 50 to 60 dBA) a 10 to 16 dBA difference was noted between the interior and exterior sound levels.

During the sound level testing, the heat recovery ventilators were running under normal operating conditions on low speed.

2.5 Ventilation Capacity Testing

The ventilation capacity of the equipment in the houses was estimated by taking flow measurements in both air streams of the heat recovery ventilators (HRVs). These flows are presented under the "Measured Flow" column in Table 2.5.1. The flows were measured using a C.E.S. flow pressure averaging element linked to a Dwyer Model 115 inclined manometer.

At the time of construction, the houses in Sudbury, Kingston and Fonthill required a balanced ventilation system with a capacity of 0.45 air changes per hour. The Erin Mills Phase I houses required a balanced system with a capacity of 0.50 air changes per hour. The Erin Mills Phase II houses could have been built to the same standard as the Phase I houses, or designed to meet the ventilation requirements laid out in the 1987 R-2000 Builder's Manual.

For the purposes of this report, the comparison of actual ventilation capacities is made with both the old technical requirements based on house

TABLE 2.3.1 **BACKDRAFT TEST RESULTS**
(Fireplace Test by the Hot Flue Method)

	Pressure Differential Required to Backdraft Fireplace	Fireplace Location	Outdoor Temp. ℃
KINGSTON			
House B	7 Pa	main floor	4
House D	10 Pa	main floor	3
House E	10 Pa	main floor	4
FONTHILL			
House A	10 Pa	main floor	3
House D	10 Pa	main floor	-1
House E	6 Pa	main floor	-1
ERIN MILLS Phase I			
House A	(a) 17 Pa (b) 15 Pa	(a) main floor (b) 2nd floor	2
House B	(a) 16 Pa (b) 13 Pa	(a) main floor (b) 2nd floor	9
House C	(a) 13 Pa (b) 13 Pa	(a) main floor (b) 2nd floor	7
House D	18 Pa	main floor	2
House E	20 Pa	basement	15
House F	14 Pa	main floor	15

All fireplaces have integral combustion inlets.

TABLE 2.4.1 **SOUND LEVEL MEASUREMENTS INSIDE THE HOUSES vs OUTSIDE THE HOUSES WITH THE HEAT RECOVERY VENTILATOR ON LOW SPEED**

	Manufacturer of HRV Unit	LEQ's (dBA) Low Speed	
		Inside	Outside
SUDBURY			
House A*	Air Changer DR150	44	40
House B	Nutone AE200	39	53
House C	Nutone AE200	42	54
House D	Air Changer DR150	31	53
House E	Air Changer DR150	33	45
KINGSTON			
House A*	Air Changer DR150	46	42
House B	Air Changer DR150	30	51
House C	Air Changer DR150	-	-
House D	Air Changer DR150	34	49
House E	Air Changer DRAP275	31	47
FONTHILL			
House A*	Air Changer DRAP275	52	45
House B*	Air Changer DR150	43	42
House C	Air Changer DR150	-	-
House D	P.M. Wright WR25	23	40
House E	Air Changer DR150	-	-
ERIN MILLS Phase I			
House A	Lifebreath 250	35	57
House B	Lifebreath 250	37	59
House C	Lifebreath 250	-	-
House D	Lifebreath 250	25	52
House E	VanEE 2000	34	56
House F	Air Changer DRAP275	30	48
House G	Lifebreath 250	44	46

* In these houses the inside sound levels were higher because of homeowner activities. For example: babies were crying, dogs were barking, and homeowners were entertaining guests.

TABLE 2.5.1 **HOUSE VENTILATION SYSTEM CHARACTERISTICS**

	Manufacturer of HRV Unit (L/s)	ACH Req'ts. (L/s)	New Tech. Req'ts. Cont. (L/s)	Int. (L/s)	Measured Flow Supply (L/s)	Exh.
SUDBURY						
House A	Air Changer DR150	62	55	80	64	43
House B	Nutone AE200	56	45	70	60	61
House C	Nutone AE200	62	50	75	74	64
House D	Air Changer DR150	61	55	80	61	61.5
House E	Air Changer DR150	67	60	85	--	--
KINGSTON						
House A	Air Changer DR150	85	70	95	70	68
House B	Air Changer DR150	78	75	100	33	55
House C	Air Changer DR150	81	70	95	58	54
House D	Air Changer DR150	65	60	85	54	55
House E	Air Changer DRAP275	85	75	100	79	86
FONTHILL						
House A	Air Changer DRAP275	87	70	95	74	87
House B	Air Changer DR150	65	60	85	47	47
House C	Air Changer DR150	73	55	80	66	56
House D	P.M. Wright WR25	85	75	100	--	--
House E	Air Changer DR150	72	55	80	50	61
ERIN MILLS Phase I						
House A	Lifebreath 250	73	55	80	54	55
House B	Lifebreath 250	73	55	80	63	64
House C	Lifebreath 250	73	55	80	55	55
House D	Lifebreath 250	73	50	75	63	63
House E	VanEE 2000	79	60	85	74	72
House F	Air Changer DRAP275	67	50	75	73	71
House G	Lifebreath 250	67	50	75	83	66
ERIN MILLS Phase II						
House H	VanEE 2000	79	60	85	68	67
House I	VanEE 2000	67	50	75	61.5	61.5
House J	VanEE 2000	67	50	75	74	74
House K	VanEE 2000	73	55	80	--	--
House L	VanEE 2000	73	55	80	70	70

volume and the new technical requirements based on ventilation per room. Table 2.5.1 shows the old air changes per hour requirements and both the continuous and intermittent peak capacities required under the new technical requirements.

The data in Table 2.5.1 reveals that most of the houses meet or exceed the new 1987 R-2000 Technical Requirements. The houses that are lower than the new 1987 R-2000 Technical Requirements are presently undergoing a retrofit program which will bring them up to the new ventilation levels.

As a general rule, ventilation capacity problems stem from three sources:

- the size of the HRV unit,
- the length of ducting and attention to minimizing flow restrictions such as elbows, and
- the location of the HRV inlet.

2.6 Combustion Appliance Efficiency Testing

The steady state combustion efficiency tests were carried out using a Neotronics Fuel Efficiency Monitor on all but one of the combustion space heating appliances installed in the houses being monitored. The results of tests are shown in Table 2.6.1 along with the make and model of each appliance. At House E in Kingston the exhaust piping of the Lennox Pulse unit did not lend itself to combustion efficiency measurement.

The steady state furnace efficiencies range from 67 percent for a standard non-induced draft unit to 86 percent for a sealed combustion condensing unit.

2.7 Construction Reliability

Throughout the course of the monitoring program, inspections were carried out and the homeowners questioned to determine the extent of any construction-related problems. From this standpoint, the houses have performed extremely well. There has been no evidence of moisture accumulation, including mildew, mold or water staining around windows.

As was also reported last year, the structural integrity of the basements appears to be very good with none of the houses experiencing water leakage or significant cracking.

TABLE 2.6.1 **COMBUSTION EFFICIENCY TESTS**

	Furnace Type	Make	Efficiency 1985 1986	Efficiency 1986 1987
SUDBURY				
House B	Natural Gas	Olsen Minimax	69%*	73%*
House C	Natural Gas	Olsen Minimax	71%*	-
House D	Natural Gas	Olsen Minimax	67%*	77%*
House E	Natural Gas	Olsen Duamatic Ultramax	86%	86%
KINGSTON				
House E	Natural Gas	Lennox Pulse	Measurement not Possible	
FONTHILL				
House A	Natural Gas	York	83%	83%
House B	Natural Gas	York	85%	84%

All other houses were heated electrically.

* The determination of efficiency of these units was difficult due to the close proximity of the burner to the dilution air port on the furnace.

3.0 ENERGY MONITORING

The major purpose of the energy monitoring portion of the program is to quantify the energy use in each house and to compare these actual monitored results with the original computer predictions.

HOTCAN and HOT-2000 computer simulation programs are used in the R-2000 Program. HOTCAN was originally developed through the National Research Council of Canada. The program, using building parametric inputs including areas, thermal resistance values, and orientations, as well as, average climatic data for the location, computes an annual summary of estimated energy load. HOT-2000 is an adaption and development of HOTCAN supported by Energy, Mines and Resources Canada. The data available for this report covers the period from September 1985 to June 1987. For the comparisons of HOTCAN and HOT-2000, data for the period May 1, 1986 to April 30, 1987 is used.

Energy monitoring was achieved by installing submeters to segregate the energy used for space heating and the energy used for domestic hot water heating from the total energy used. The meter readings are obtained on a monthly basis during the regular site visit from the submeters and the total energy meters supplied by the local gas and electric utilities for energy billing purposes. Where gas was used for space heating or domestic hot water heating the consumption figures used in the report are adjusted for the efficiency of the appliance.

Sufficient energy data is not yet available for the houses being monitored in the Erin Mills Phase II project and hence no energy data from these units is presented in this report.

A complete summary of all the energy data for the full monitoring period is included in Appendix C.

3.1 Total Energy Use

Total energy use varied significantly from the HOTCAN predicted quantities. The comparison of HOTCAN predicted consumptions and actual consumptions from May 1, 1986 to April 30, 1987 are shown in Table 3.1.1.

TABLE 3.1.1 **TOTAL ANNUAL ENERGY CONSUMPTION***

	ACTUAL** (kWh) (85/86)	ACTUAL HOTCAN (85/86)	ACTUAL (kWh) (86/87)	ACTUAL HOTCAN (86/87)
SUDBURY				
House A	20731	1.25	21779	1.31
House B	24538	1.36	22665	1.26
House C	21319	1.14	18891	1.01
House D	26119	1.37	22592	1.19
House E	24485	1.22	23734	1.18
KINGSTON				
House A	25517	1.34	26769	1.41
House B	28332	1.54	25690	1.40
House C	24522	1.27	28749	1.49
House D	18025	1.05	20818	1.21
House E	24368	1.21	20263	1.01
FONTHILL				
House A	23995	1.31	24694	1.35
House B	24440	1.43	23261	1.36
House C	25170	1.47	15506	0.91
House D	24170	1.30	20823	1.12
House E	23672	1.37	21564	1.25
ERIN MILLS Phase I				
House A	18163	1.06	22842	1.33
House B	29562	1.65	25614	1.43
House C	22749	1.31	21504	1.24
House D	20701	1.15	19516	1.08
House E	34612	1.65	28516	1.36
House F	19540	1.21	13396	0.83
House G	19104	1.24	19743	1.28

Notes:

* includes space heating, domestic hot water heating and all electrical energy.

** Actual energy consumption has been extrapolated to a full year's data from eight months of monitored data.

3.2 Space Heating

In the evaluation of the energy performance of the R-2000 houses being monitored, space heating is the most important quantity to examine. Space heating requirements, although affected by occupant lifestyles, are the primary focus of R-2000 technology.

The major external factor affecting space heating requirements is the actual weather conditions. Appendix B contains the degree day data for the monitoring period along with the average degree day data for each community.

The comparison of the original HOTCAN predictions of annual space heating energy consumption with the annual monitored quantities are presented in Table 3.2.1.

The monitoring results indicate that the average house used twenty nine percent more energy than predicted by HOTCAN for space heating. This average percentage is somewhat misleading in that a significant portion of the variance between the actual and the predicted values is the result of the high actual space heating energy consumption in the Erin Mills houses. Excluding these units, the average actual consumption was thirteen percent higher than the original HOTCAN prediction

Figure 3.2.1 illustrates the variation in HOTCAN predicted space heating energy consumption versus the actual energy consumed for the monitored houses.

Table 3.2.2 presents the predicted R-2000 Target space heating energy consumption and the actual energy consumed in the monitored houses. This variation is illustrated in Figure 3.2.2.

The variations between the different predictions of space heating energy consumption are clearly demonstrated in Figures 3.2.3 and 3.2.4. These figures contain bar graphs for the four communities illustrating the actual space heating energy consumption per square metre of floor area and the space heating energy requirements per square metre of floor area predicted using HOTCAN, HOT-2000 and the R-2000 Target for each house.

The individual plots of the actual monthly energy use and the predicted HOTCAN use are included with the house profiles presented in Appendix A for the full monitoring period. A typical HOTCAN printout was presented in the 1986 monitoring report.

TABLE 3.2.1 **ANNUAL SPACE HEATING ENERGY CONSUMPTION**
(Actual 1986/87, HOTCAN, HOT-2000 and R-2000 Target)

	Actual 86/87 (kWh/y)	HOTCAN Predicted (kWh/y)	Actual HOTCAN	HOT-2000 Predicted (kWh/y)	R-2000 Target (kWh/y)
SUDBURY					
House A	10322	8809	1.17	8951	8964
House B	6161	7866	0.78	9218	8150
House C	6735	8432	0.80	9846	8910
House D	7694	8851	0.81	10508	8783
House E	8460	9782	0.86	9387	8946
KINGSTON					
House A	10434	8881	1.17	8393	9918
House B	10467	8170	1.28	7721	9031
House C	10672	9021	1.18	8654	9409
House D	8234	6935	1.19	6495	7577
House E	6860	9920	0.69	9085	9918
FONTHILL					
House A	10654	8160	1.31	11770	9306
House B	9397	6898	1.36	10104	6926
House C	7585	6855	1.11	7477	7755
House D	13463	8356	1.61	13658	9078
House E	11053	7031	1.57	8180	7661
ERIN MILLS Phase I					
House A	13316	6909	1.93	-	7548
House B	14792	7684	1.93	-	7620
House C	12635	7111	1.78	-	7620
House D	12303	7810	1.58	-	7548
House E	17417	0775	1.62	-	8299
House F	5525	5952	0.93	-	6926
House G	8322	5154	1.61	-	6926

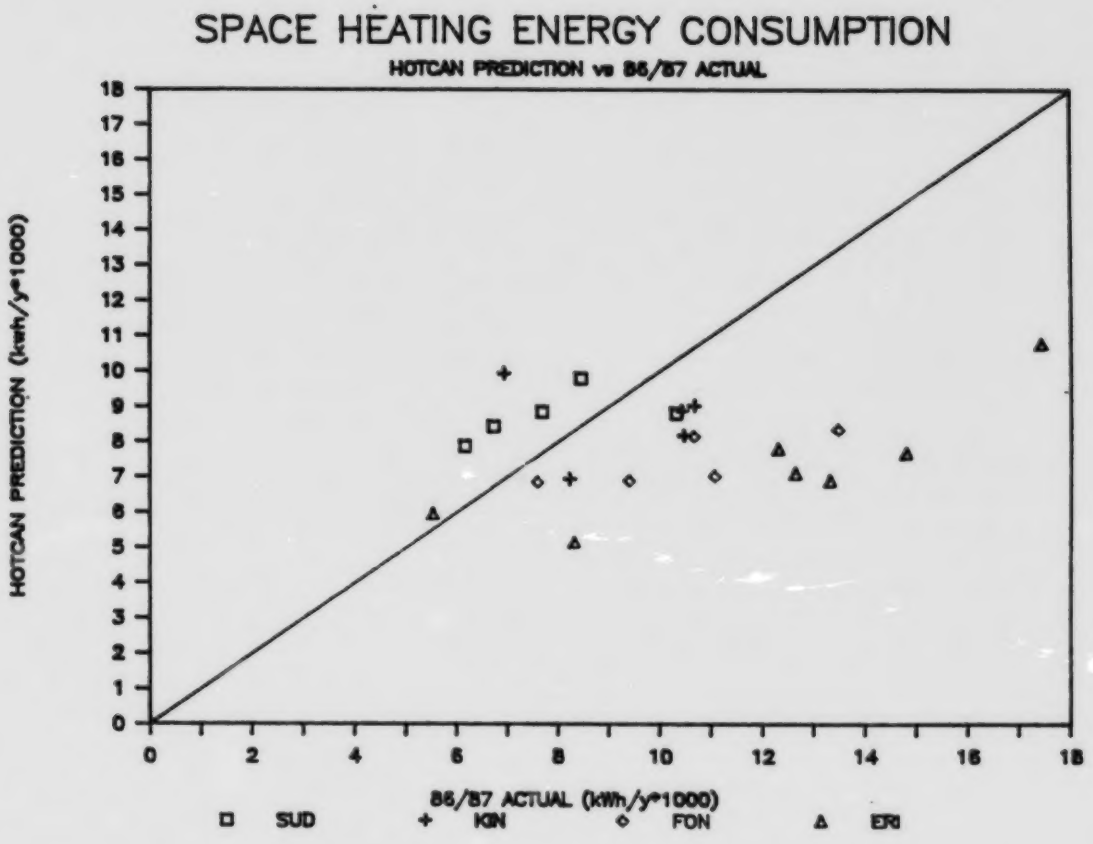

SPACE HEATING ENERGY CONSUMPTION
HOTCAN PREDICTION vs 86/87 ACTUAL
HOTCAN PREDICTION (kwh/y*1000)
86/87 ACTUAL (kWh/y*1000)
SUD
KIN
FON
ERI

Figure 3.2.1

TABLE 3.2.2 **SPACE HEATING ENERGY CONSUMPTION**
(R-2000 Target and Actual 1986/87)

	R-2000 Target (kWh/d)	Actual 86/87 (kWh/d)
SUDBURY		
House A	24.6	28.3
House B	22.3	16.9
House C	24.4	18.5
House D	24.1	21.1
House E	24.5	23.2
KINGSTON		
House A	27.2	28.6
House B	24.7	28.7
House C	25.8	29.2
House D	20.8	22.6
House E	27.2	18.8
FONTHILL		
House A	25.5	29.2
House B	19.0	25.7
House C	21.2	20.8
House D	24.9	36.9
House E	21.0	30.3
ERIN MILLS Phase I		
House A	20.7	36.5
House B	20.9	40.5
House C	20.9	34.6
House D	20.7	33.7
House E	22.7	47.7
House F	19.0	15.1
House G	19.0	22.8

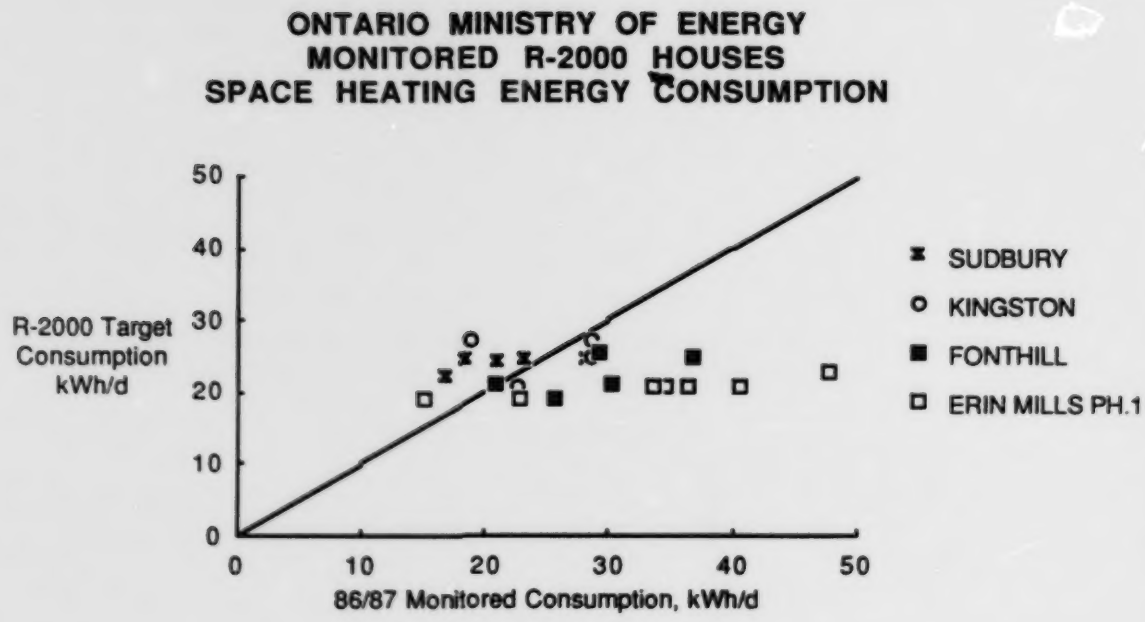
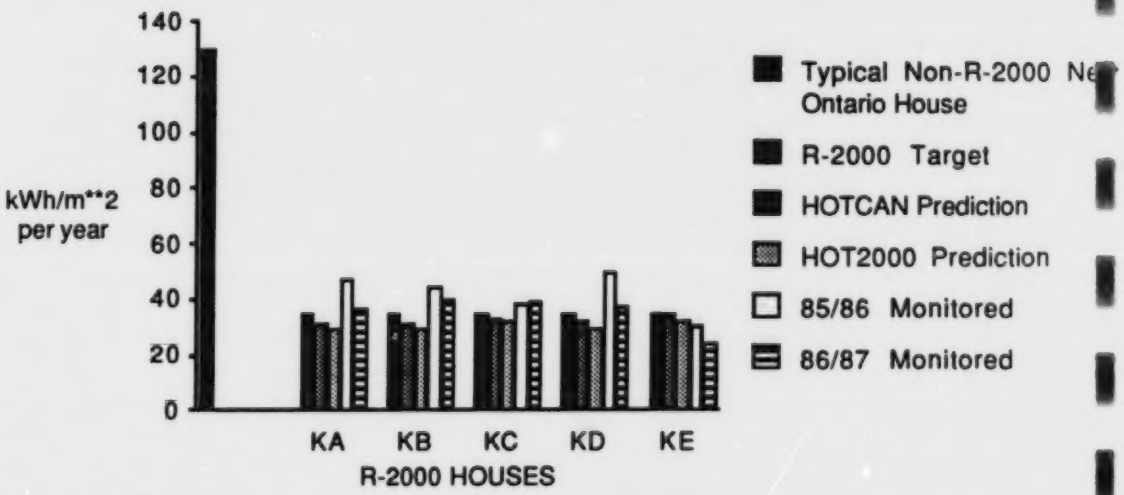

ONTARIO MINISTRY OF ENERGY
MONITORED R-2000 HOUSES
SPACE HEATING ENERGY CONSUMPTION
R-2000 Target Consumption kWh/d
86/87 Monitored Consumption, kWh/d
0
10
20
30
40
50
SUDBURY
KINGSTON
FONTHILL
ERIN MILLS PH.1

Figure 3.2.2

SPACE HEATING ENERGY CONSUMPTION PER SQUARE METRE OF FLOOR AREA

Sudbury, Ontario

SPACE HEATING ENERGY CONSUMPTION PER SQUARE METRE OF FLOOR AREA



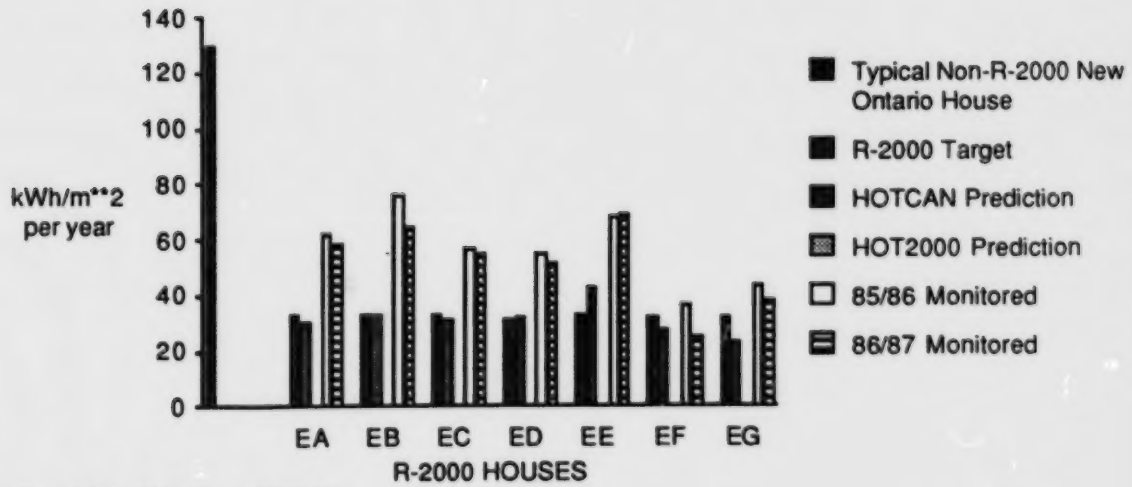
Kingston, Ontario

Figure 3.2.3

SPACE HEATING ENERGY CONSUMPTION PER SQUARE METRE OF FLOOR AREA

Fonthill, Ontario

SPACE HEATING ENERGY CONSUMPTION PER SQUARE METRE OF FLOOR AREA



Erin Mills Phase I, Ontario

Figure 3.2.4

3.3 Domestic Hot Water Heating

Domestic hot water use and the energy required to heat it for each house is shown in Table 3.3.1. HOTCAN uses a standard consumption of 14 kWh per day or 5110 kWh per year.

The average house consumed 14.02 kWh per day of hot water. For the individual houses, the domestic hot water usage ranged from seventy two percent above the HOTCAN assumed value to forty percent below the assumed value.

TABLE 3.3.1 **ANNUAL DOMESTIC HOT WATER LOAD**

	Flow (m^3)	Energy (kWh)
SUDBURY		
House A	86.2	4792
House B	97.4	5350
House C**	53.9	3770
House D	87.6	4782
House E	70.4	5172
KINGSTON		
House A	71.1	4293
House B	100.8	7284
House C	134.0	8796
House D	47.8	3803
House E	53.2	3877
FONTHILL		
House A	81.0	5029
House B	100.9	7160
House C *	45.9	3091
House D	55.2	4800
House E	-	4104
ERIN MILLS Phase I		
House A	59.1	4593
House B	88.3	6061
House C	70.4	4865
House D	57.6	3468
House E	116.1	7516
House F	66.5	5164
House G	66.0	4754

Note: * House unoccupied between July 1986 and February 1987.
** Induced draft gas heater, assumed efficiency of 60%.

4.0 AIR QUALITY ANALYSIS

The air quality analysis undertaken for this study has centered on the measurement of four potential pollutants. These include:

- formaldehyde,
- radon,
- carbon dioxide, and
- carbon monoxide.

Formaldehyde, carbon dioxide and carbon monoxide are measured using diffusion-type samplers. The samplers are deployed in each house during the monthly site visit and returned one week later by the homeowner to Buchan, Lawton, Parent Ltd. using supplied preaddressed courier envelopes. Radon sampling is done on a three-month rotation with the samplers deployed during one site visit and removed during the site visit three months later.

Throughout the program, formaldehyde sampling has been done with Air Quality Research Incorporated diffusion PF1 sampler tubes. Radon sampling has been carried out using Terradex sample cups. Carbon monoxide and carbon dioxide sampling has been carried out using Drager diffusion tubes.

The Drager diffusion tubes used for carbon monoxide and carbon dioxide sampling were originally designed for eight hour exposures at relatively high pollutant concentrations. Buchan, Lawton, Parent Ltd. has been using these tubes for seven day exposures at the relatively low pollutant concentrations expected in indoor residential environments. A major chamber calibration study was undertaken to characterize these devices under the seven day exposure conditions.

4.1 Formaldehyde Sampling

Formaldehyde sampling is taken in two locations in each of the houses. One location is in the area of the dining room, the second location is in a bedroom. In general, no significant difference has been found between readings in the bedroom and the dining room in any individual house.

A review of the data reveals several significant trends. Four percent of all samples taken have exceeded the currently accepted long-term exposure limit of 0.1 parts per million of formaldehyde. Forty one percent of all samples taken have exceeded the Health and Welfare Canada suggested limit on long-term exposure to formaldehyde of 0.05 parts per million.

The collected data illustrates a very strong annual cycle in formaldehyde concentrations. Figure 4.1.1 shows the average formaldehyde concentration for the entire monitoring sample on a monthly basis from September 1985 to June 1987. This figure shows summer formaldehyde concentrations peaking, on average, to approximately twice the mid-winter concentration. This strong seasonal relationship occurs in all of the houses being monitored. Figures 4.1.2 to 4.1.5 contain the individual plots for each

community. This trend is consistent with the strong humidity dependence of formaldehyde release.

Average and peak concentrations for each house are shown in Table 4.1.1.

4.2 Radon Sampling

All radon measurements were well below the recommended maximum long-term exposure levels proposed by Health and Welfare Canada of 21 picocuries per litre.

The highest radon reading encountered was 7.7 picocuries per litre. Over the monitoring period the highest average radon level, 4.3 picocuries per litre, occurred in the same house.

Approximately nine percent of the readings exceeded the level of four picocuries per litre. This level of radon exposure was previously accepted as the appropriate maximum long-term exposure level.

The average and peak concentrations for each house over the monitoring period are presented in Table 4.2.1.

4.3 Carbon Dioxide Sampling

During each site visit, carbon dioxide diffusion tube samplers were located in two locations in each house. The readings between the two samplers, in almost all cases, were very consistent.

Figure 4.3.1 illustrates the detected carbon dioxide concentrations in the monitored sample on a monthly basis. A strong seasonal dependence is shown with peaks occurring in the fall/winter seasons. All readings were below the proposed Health and Welfare Canada standard of 3500 parts per million and the ASHRAE recommended exposure level of 1500 parts per million.

The average and peak concentrations for each house are shown in Table 4.3.1.

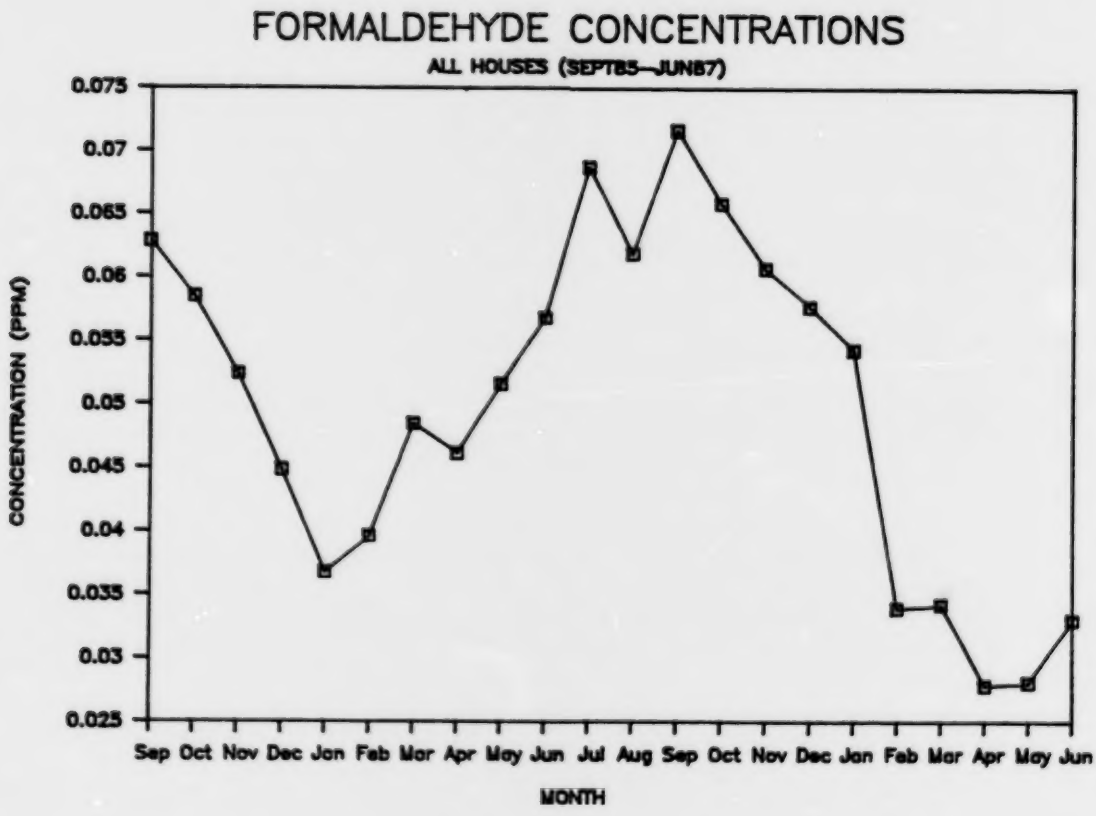
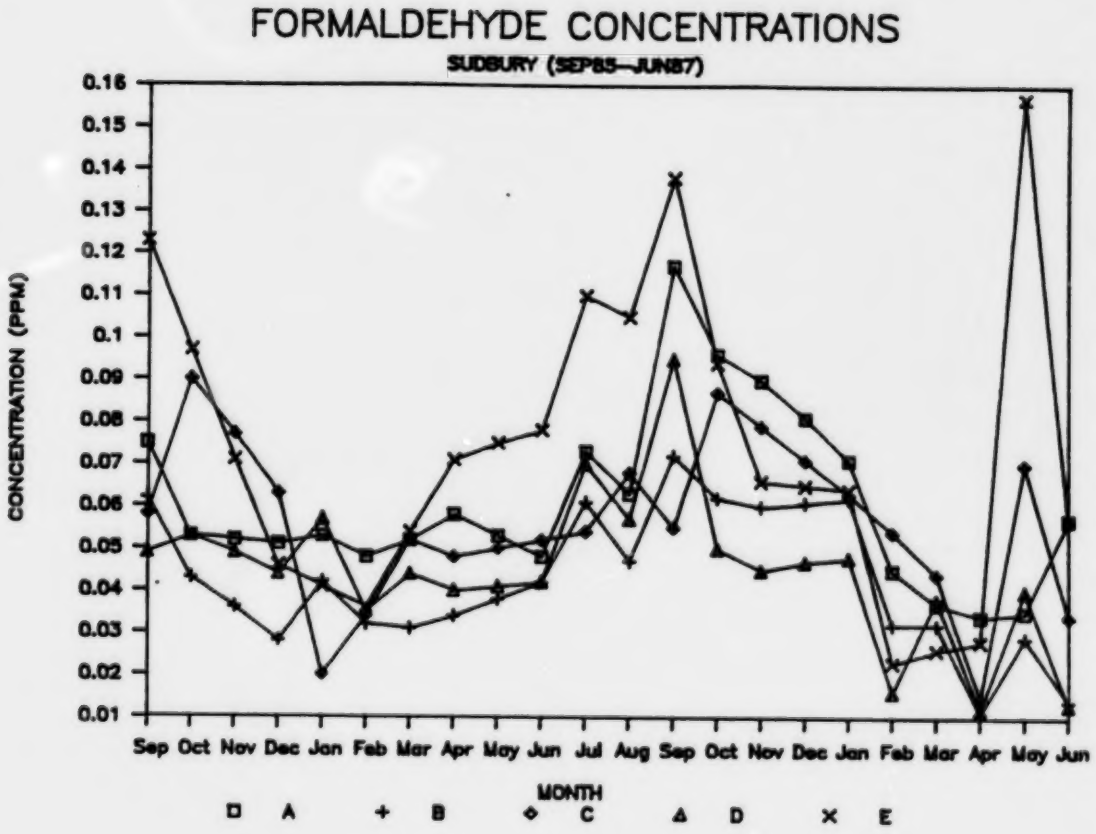

FORMALDEHYDE CONCENTRATIONS
ALL HOUSES (SEPT85–JUN87)
CONCENTRATION (PPM)
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun
MONTH

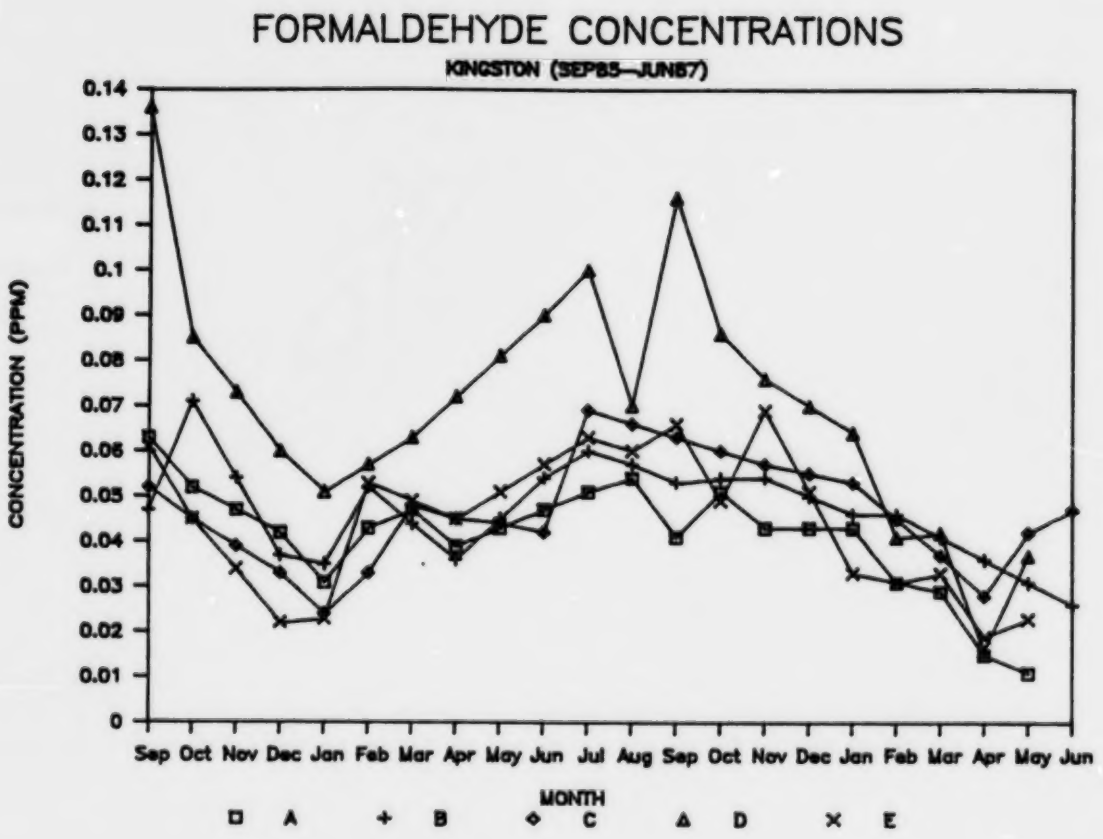
Figure 4.1.1



LEGEND

Sudbury Houses A to E

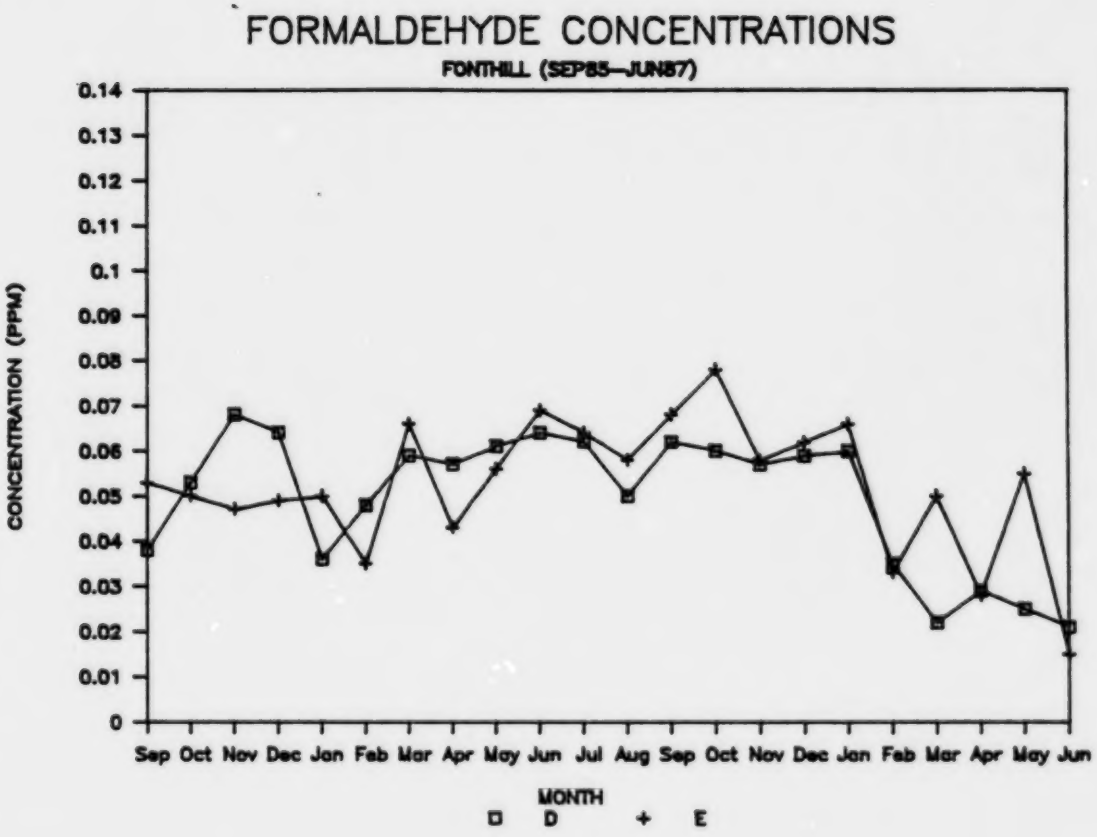
Figure 4.1.2



LEGEND

Kingston Houses A to E

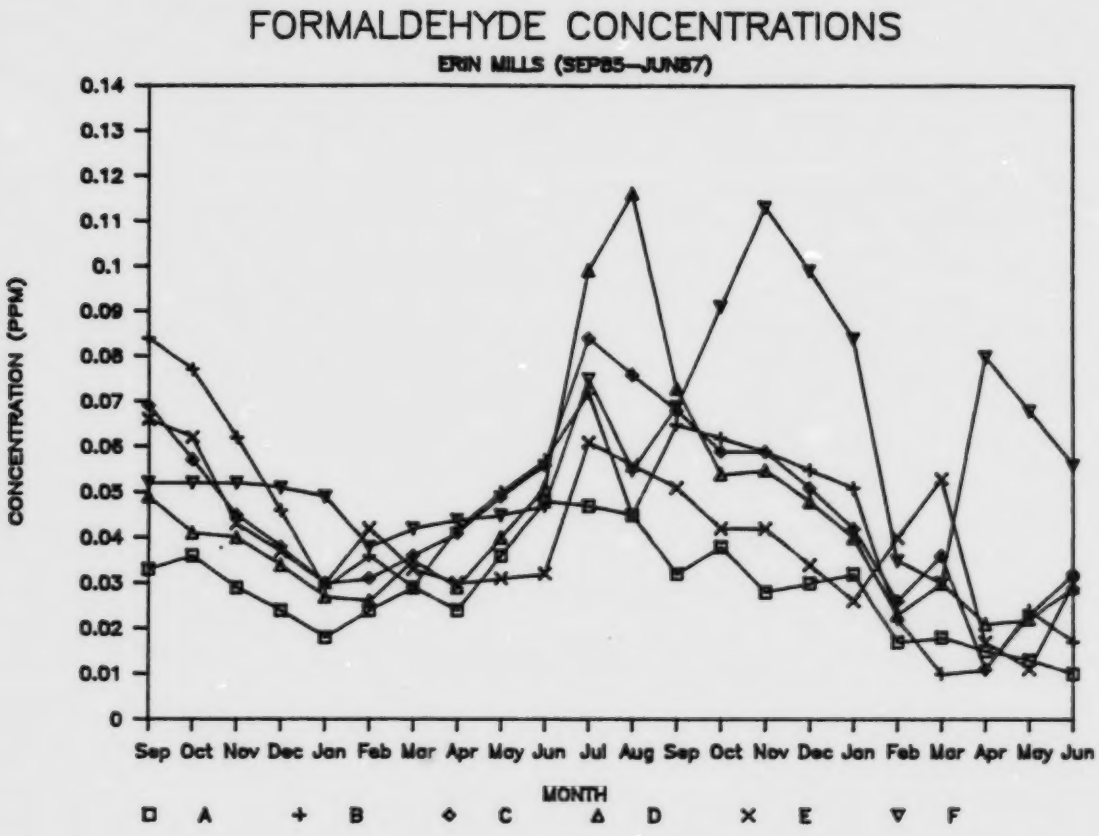
Figure 4.1.3



LEGEND

Fonthill Houses D and E

Figure 4.1.4



LEGEND

Erin Mills Houses A to F

Figure 4.1.5

TABLE 4.1.1 **FORMALDEHYDE CONCENTRATIONS**

	Average (ppm)	Maximum (ppm)
SUDBURY		
House A	0.061	0.130
House B	0.049	0.081
House C	0.054	0.096
House D	0.045	0.101
House E	0.072	0.165
KINGSTON		
House A	0.040	0.067
House B	0.046	0.075
House C	0.043	0.071
House D	0.069	0.149
House E	0.043	0.082
FONTHILL		
House A	0.041	0.080
House B	-	-
House C	0.050	0.111
House D	0.050	0.123
House E	0.052	0.083
ERIN MILLS Phase I		
House A	0.028	0.054
House B	0.043	0.091
House C	0.043	0.092
House D	0.045	0.121
House E	0.037	0.069
House F	0.031	0.121
House G	0.041	0.073
ERIN MILLS Phase II		
House H	0.034	0.064
House I	0.025	0.036
House J	0.031	0.047
House K	0.026	0.037
House L	0.042	0.061

TABLE 4.2.1 **RADON CONCENTRATIONS**

	Average (pCi/L)	Maximum (pCi/L)
SUDBURY		
House A	1.75	3.50
House B	1.45	2.46
House C	1.81	3.20
House D	2.97	5.50
House E	2.85	5.80
KINGSTON		
House A	0.59	1.00
House B	0.94	2.30
House C	0.87	2.07
House D	1.94	4.70
House E	4.33	7.70
FONTHILL		
House A	1.07	2.46
House B	0.70	1.60
House C	1.68	4.50
House D	2.51	5.10
House E	2.28	5.40
ERIN MILLS Phase I		
House A	1.54	5.50
House B	0.81	2.50
House C	1.56	5.30
House D	1.44	6.50
House E	0.76	1.70
House F	1.46	4.80
House G	0.94	2.60
ERIN MILLS Phase II		
House H	0.35	0.70
House I	0.60	0.60
House J	0.30	0.30
House K	0.45	0.50
House L	-	-

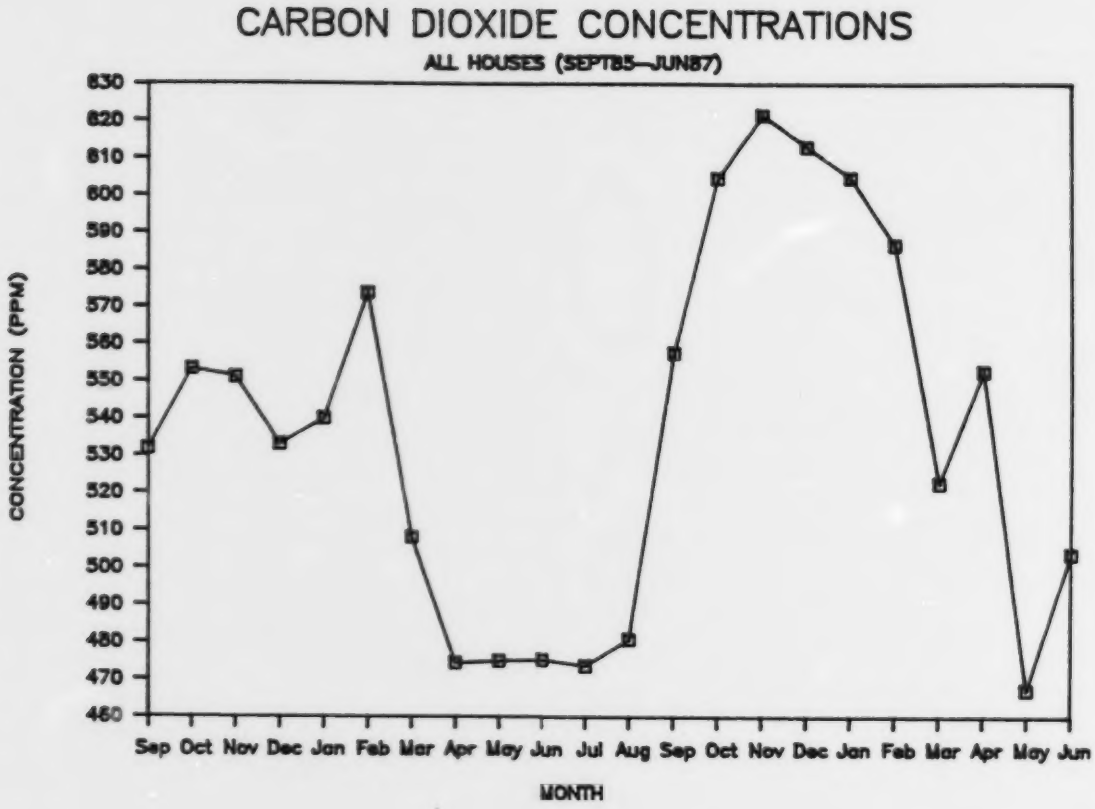

CARBON DIOXIDE CONCENTRATIONS
ALL HOUSES (SEPT85—JUN87)
CONCENTRATION (PPM)
630
620
610
600
590
580
570
560
550
540
530
520
510
500
490
480
470
460
Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun
MONTH

Figure 4.3.1

TABLE 4.3.1 **CARBON DIOXIDE CONCENTRATIONS**

	Type of Heating System	Average (ppm)	Maximum (ppm)
SUDBURY			
House A	5	524	786
House B	3	606	899
House C	3	627	1151
House D	3	621	822
House E	2	553	734
KINGSTON			
House A	4	474	594
House B	4	501	591
House C	4	492	562
House D	4	574	807
House E	1	635	933
FONTHILL			
House A	2	486	574
House B	2	-	-
House C	4	503	664
House D	4	555	829
House E	4	494	713
ERIN MILLS Phase I			
House A	4	515	613
House B	4	450	542
House C	4	542	661
House D	4	453	546
House E	4	473	604
House F	4	501	997
House G	4	448	565
ERIN MILLS Phase II			
House H	4	414	501
House I	4	447	642
House J	4	395	479
House K	4	441	487
House L	4	385	429

TYPES OF HEATING SYSTEMS:

1. Pulse gas forced air
2. Induced draft gas forced air
3. Naturally asperating gas forced air
4. Electric forced air
5. Electric base board heaters

4.4 Carbon Monoxide Sampling

Carbon monoxide samplers were also deployed in two locations in each house. The locations, such as near fireplaces and combustion furnaces, were selected to reflect combustion sources.

During the early portion of the monitoring program, data was not available from the carbon monoxide sensors due to defective Drager tube samplers. The Drager company recalled the samplers because of a manufacturing fault. For this reason, data is only available for the period beginning in February 1986. In October 1986, a switch was made from Drager to Gastec sampling tubes for reasons of availability and cost.

Because of the low concentrations of carbon monoxide found in all houses, no trends can be identified. The peak concentrations were less than six parts per million and the average concentrations for all houses were below four parts per million.

The average and peak concentrations for each house are shown in Table 4.4.1.

TABLE 4.4.1 **CARBON MONOXIDE CONCENTRATIONS**

	Type of Heating System	Average (ppm)	Maximum (ppm)
SUDBURY			
House A	5	0.45	1.36
House B	3	1.55	3.41
House C	3	2.02	3.14
House D	3	0.63	1.67
House E	2	1.23	2.85
KINGSTON			
House A	4	0.68	1.84
House B	4	0.38	1.55
House C	4	0.73	1.75
House D	4	1.83	3.18
House E	1	0.87	2.05
FONTHILL			
House A	2	0.94	2.23
House B	2	-	-
House C	4	0.94	1.55
House D	4	1.14	3.36
House E	4	0.96	3.05
ERIN MILLS Phase I			
House A	4	1.58	3.22
House B	4	1.10	2.40
House C	4	1.72	3.06
House D	4	0.88	2.19
House E	4	1.56	2.74
House F	4	1.45	2.84
House G	4	1.58	5.74
ERIN MILLS Phase II			
House H	4	3.05	4.65
House I	4	1.66	2.35
House J	4	1.19	1.48
House K	4	2.45	3.08
House L	4	2.96	3.74

TYPES OF HEATING SYSTEMS:

1. Pulse gas forced air
2. Induced draft gas forced air
3. Naturally asperating gas forced air
4. Electric forced air
5. Electric base board heaters

5.0 DETAILED MONITORING

5.1 Description of Monitoring Equipment

One house was selected for detailed monitoring in each of the monitored communities. The houses chosen were House B in Sudbury, House E in Kingston, House A in Fonthill and House G in Erin Mills.

The detailed monitoring consists of minute-by-minute measurement and the hourly recording of average temperatures and humidities throughout the houses, as well as, the detailed performance monitoring of the operation of the mechanical systems. Under the program, the emphasis is placed on the operation of the heat recovery ventilator unit.

No modifications have been made to the monitoring installations and hence the monitoring equipment and sensor locations are identical to those reported in the previous year's monitoring report.

5.2 HRV Performance

This subsection of the report deals with the performance of the heat recovery ventilators (HRVs) as monitored by the data acquisition systems.

HRV performance is expressed in terms of heat recovery efficiency and apparent sensible effectiveness. The first is defined as follows:

$$\text{heat recovery efficiency} = \frac{(m_{sup})\,(h_2 - h_1) - Qf}{(m_{exh}\,h_{3s} - m_{sup}\,h_{1s}) + Qf}$$

where:

m_{sup} = supply mass flow
m_{exh} = exhaust mass flow
h_1 = enthalpy of air at cold supply (sensible and latent)
h_{1s} = enthalpy of air at cold supply (sensible)
h_2 = enthalpy of air at warm supply (sensible and latent)
h_3 = enthalpy of air at warm exhaust (sensible and latent)
h_{3s} = enthalpy of air at warm exhaust (sensible)
Qf = fan dissipation heat factor (dependent on model and fan speed listed at top of following page)

FAN DISSIPATION HEAT FACTOR VALUES (Qf)

HRV model	Speed	Qf (kW)
Air Changer DRP-275	low	0.055
	high	0.14
Lifebreath 250	low	0.03
	high	0.085
Nutone AE500	not available	

Apparent sensible effectiveness is defined as:

$$\text{apparent sensible effectiveness} = \frac{m_{sup}(t_2-t_1)-Q_f}{m_{min}(t_3-t_1)+Q_f}$$

where:

m_{min} = minimum mass flow rate (between supply and exhaust
t_2 = dry bulb temperature at warm supply
t_1 = dry bulb temperature at cold supply
t_3 = dry bulb temperature at warm exhaust

This indicator does not include the effects of latent heat in the air flow and will, therefore, produce a higher value than efficiency.

The HRV monitoring began in September 1985. The first report included results up to April 1986. The monitoring period reviewed in this report extends from May, 1986 to May, 1987.

Table 5.2.1 provides a comparison of average flow conditions for both monitoring periods. There is also a comparison of the actual net ventilation effect defined to be the larger of the two flows. In the second monitoring period, all houses provided at least 70 percent of the required rate. No clear conclusion can be reached concerning flow degradation between the two monitoring periods due to the unique histories of each HRV installation.

The exhausting air transfer ratio (cross flow) is assumed to be zero in all HRV calculations.

TABLE 5.2.1 **HRV VOLUME FLOW PERFORMANCE**

Continuous Operation
(Low Speed)

		First Year				Second Year			
Location	Req'd	Sup	Exh	Bal	A/R	Sup	Exh	Bal	A/R
Sudbury	45	50	59	0.8	1.31	29	40	0.7	0.89
Kingston	75	33	54	0.6	0.72	37	54	0.7	0.72
Fonthill	70	38	38	1.0	0.54	46	57	0.8	0.80
Erin Mills	50	40	43	0.9	0.86	26	42	0.6	0.89

Intermittent Operation
(High Speed)
Second Year

Location	Req'd	Sup	Exh	Bal	A/R
Sudbury	70				
Kingston	100	62	75	0.8	0.75
Fonthill	95	72	92	0.8	0.97
Erin Mills	75	65	67	1.0	0.89

Legend:
(all flow units are L/s)
Req'd = required (as per R-2000 Guidelines)
Sup = supply flow
Exh = exhaust flow
Bal = balance (supply/exhaust)
A/R = actual/required (actual is largest of the two flows)

5.2.1 Nutone AE-500 in Sudbury

A complete analysis of the HRV performance during the heating season is not possible due to persistent problems with the HRV. Consistent with past operating problem experience, the heat wheel drive belt broke in November, 1986 and was not repaired until April, 1987. As a result, the heat wheel did not rotate, and the flows decreased and fluctuated as the heat wheel became clogged with dirt. The heat wheel drive belt broke due to ice formation on the heat wheel causing it to drag.

Figure 5.2.1 illustrates the functioning of the HRV before and after failure of the heat wheel. There is a noticeable degradation of flows throughout the summer (about a 35 percent reduction) as a result of dirt accumulation. In April, the HRV was thoroughly cleaned and a new drive belt was installed. The flows subsequently increased by 70 percent above the values just before the belt broke.

Figure 5.2.2 shows the heat recovery efficiency and effectiveness for the entire monitoring period. During this time, there was no defrost or high speed operation.

5.2.2 Air Changer DRAP-275 in Kingston

This HRV had quite stable flows, but was still unbalanced as it was in the previous monitoring period. Figure 5.2.3 shows these flows. The summer peaks are due to high speed operation. In February, the defrost was on approximately 12 percent of the day for two days, which reduced the flows by 35 percent.

During the heating season, the heat recovery efficiency averaged 50 percent, and the averaged effectiveness was 90 percent. The ORF test results indicate an effectiveness of 93 percent. The efficiencies and effectiveness are illustrated in Figure 5.2.4.

The exhaust flow reduction with ambient temperature is shown in Figure 5.2.5. This pattern is similar to that obtained in the first monitoring period. As would be expected, there is also a correlation of the recovery efficiency to ambient temperature, as shown in Figure 5.2.6. The recovery efficiency increased during the winter months as the potential heat to be recovered increased with increasing temperature differences across the HRV. During a brief few days in July, the HRV was cooling the supply air, and the efficiencies were slightly negative. This cooling effect, however, was very small.

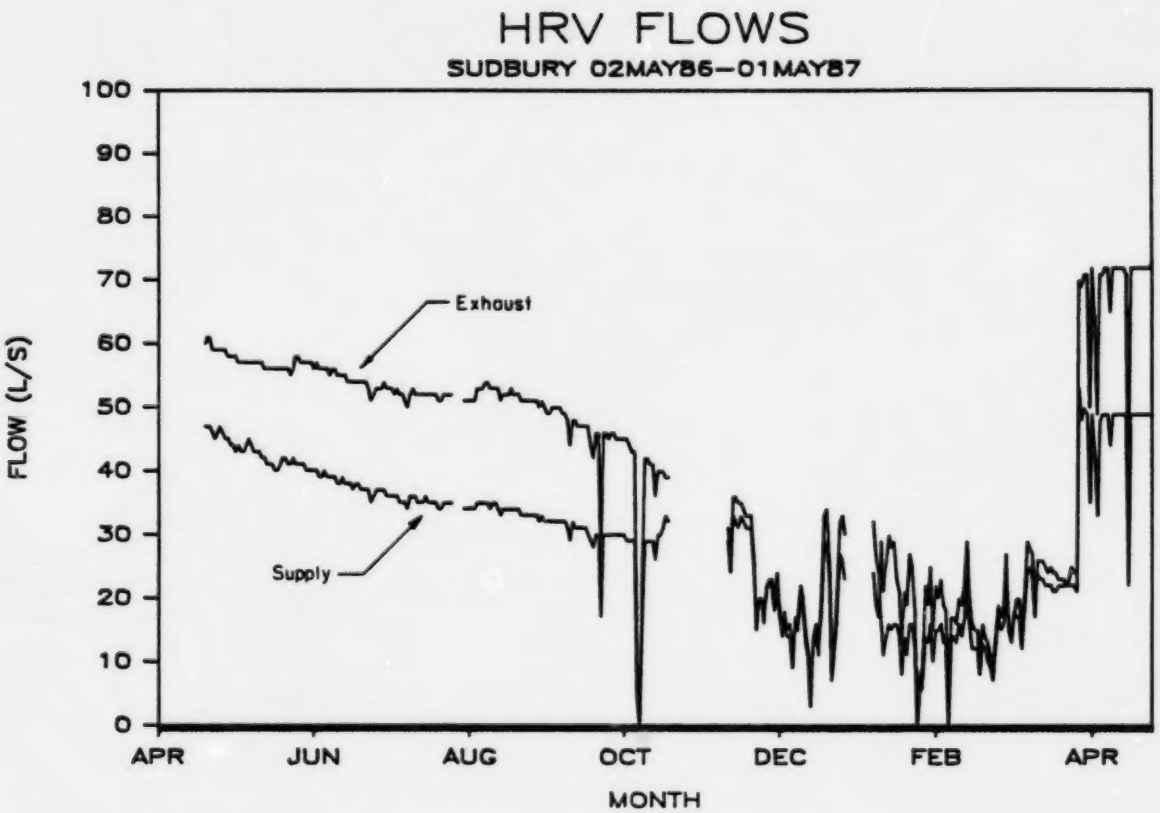

HRV FLOWS
SUDBURY 02MAY86–01MAY87
FLOW (L/S)
100
90
80
70
60
50
40
30
20
10
0
Exhoust
Supply
APR
JUN
AUG
OCT
DEC
FEB
APR
MONTH

Figure 5.2.1

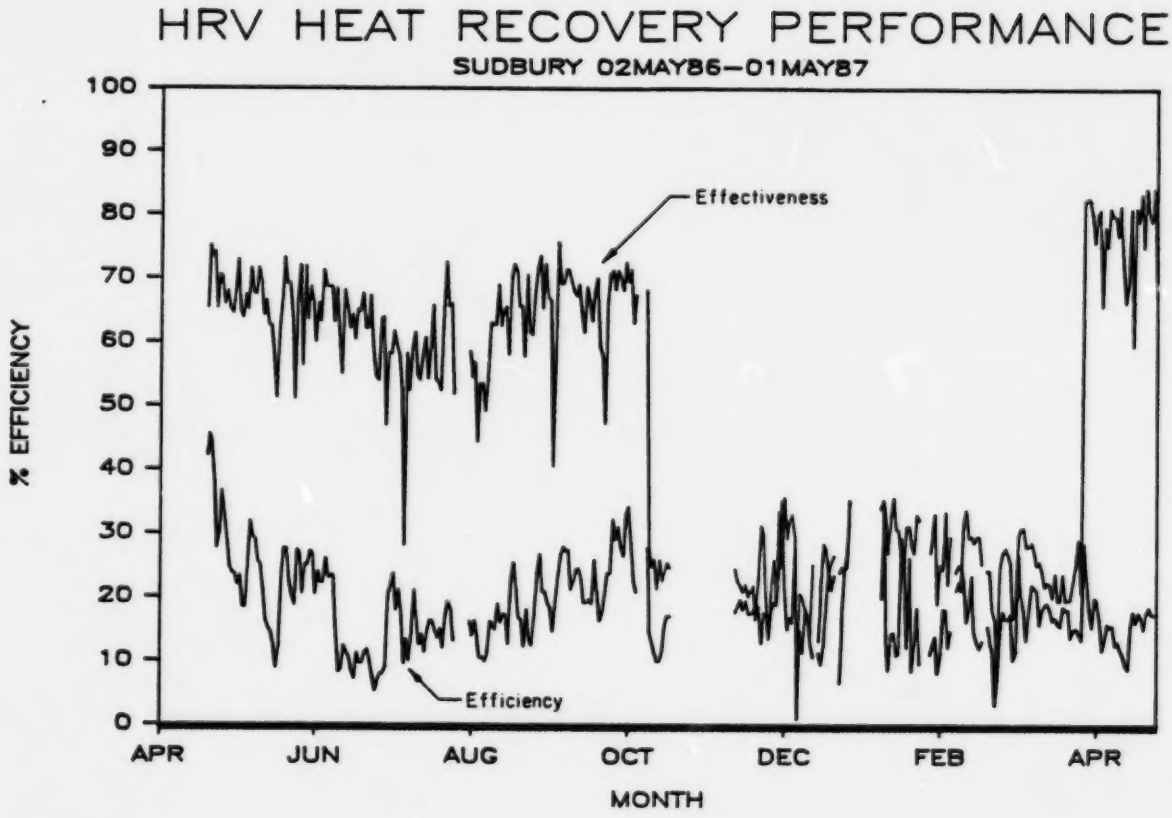

HRV HEAT RECOVERY PERFORMANCE
SUDBURY 02MAY86—01MAY87
% EFFICIENCY
100
90
80
70
60
50
40
30
20
10
0
Effectiveness
Efficiency
APR
JUN
AUG
OCT
DEC
FEB
APR
MONTH

Figure 5.2.2

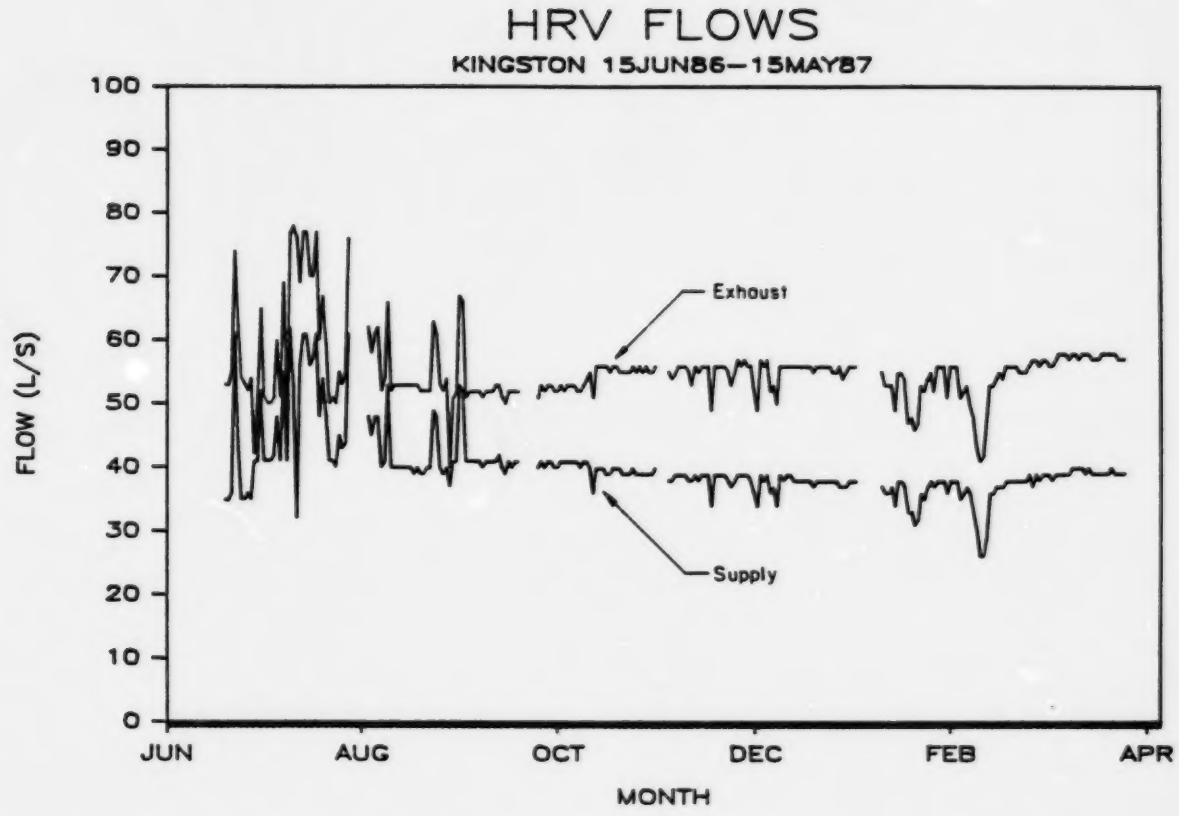

HRV FLOWS
KINGSTON 15JUN86—15MAY87
FLOW (L/S)
100
90
80
70
60
50
40
30
20
10
0
Exhaust
Supply
JUN
AUG
OCT
DEC
FEB
APR
MONTH

Figure 5.2.3

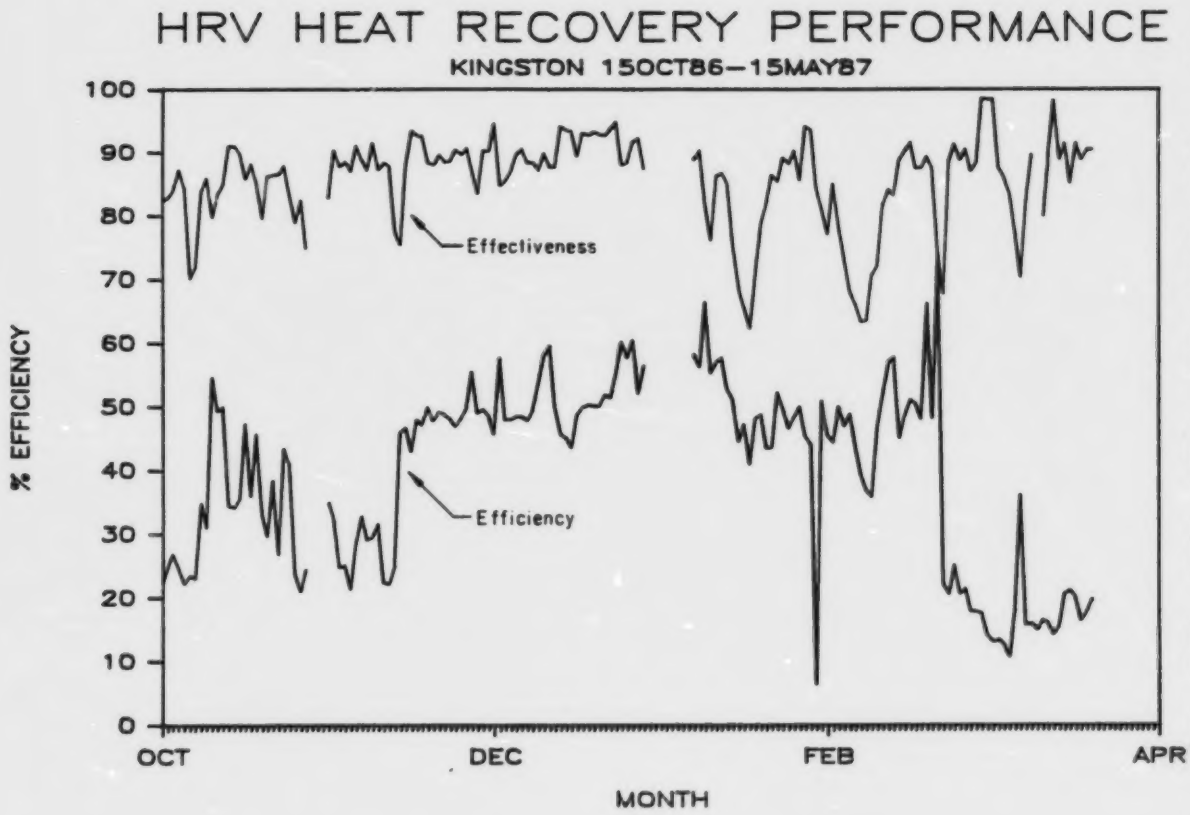

HRV HEAT RECOVERY PERFORMANCE
KINGSTON 150CT86–15MAY87
% EFFICIENCY
100
90
80
70
60
50
40
30
20
10
0
Effectiveness
Efficiency
OCT
DEC
FEB
APR
MONTH

Figure 5.2.4

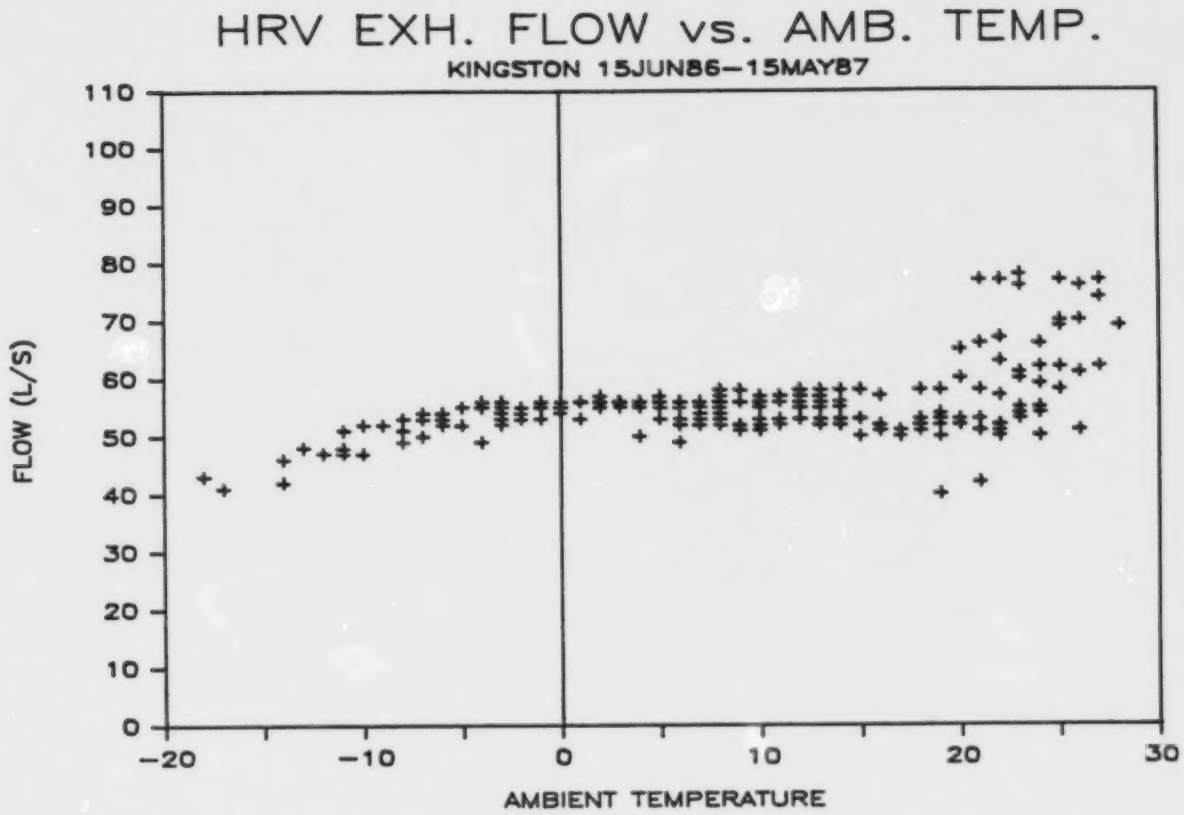

HRV EXH. FLOW vs. AMB. TEMP.
KINGSTON 15JUN86–15MAY87
FLOW (L/S)
110
100
90
80
70
60
50
40
30
20
10
0
–20
–10
0
10
20
30
AMBIENT TEMPERATURE

Figure 5.2.5

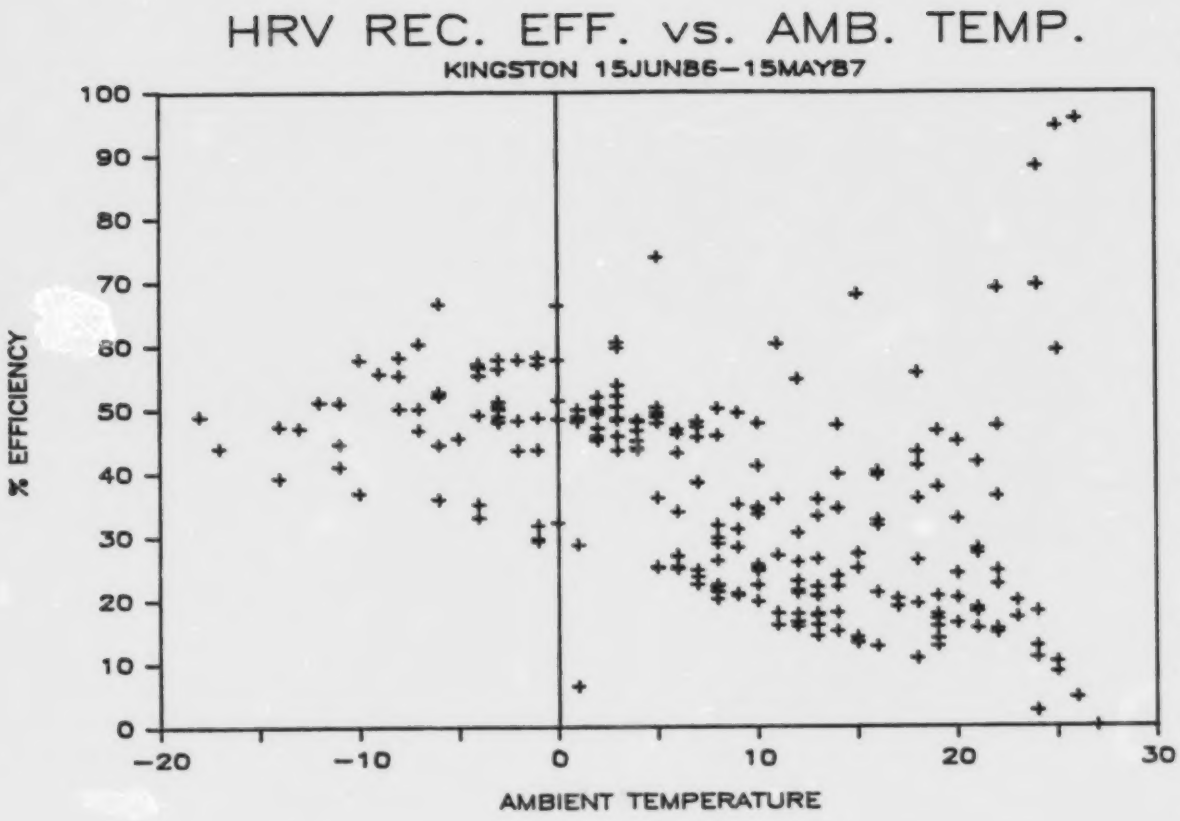

HRV REC. EFF. vs. AMB. TEMP.
KINGSTON 15JUN86–15MAY87
% EFFICIENCY
100
90
80
70
60
50
40
30
20
10
0
–20
–10
0
10
20
30
AMBIENT TEMPERATURE

Figure 5.2.6

5.2.3 Air Changer DRAP-275 in Fonthill

The flow profile of the monitored Fonthill HRV, illustrated in Figure 5.2.7, shows steady flows except for a few periods of high speed operation. The homeowner occasionally controlled the HRV fan during winter and in some cases turned the HRV off. One notable event occurred on November 11, when the accumulated debris in the supply duct grille was removed. The significant increase in both flows as a result of this simple cleaning task illustrates the importance of regular HRV maintenance and the susceptibility of HRV performance to flow interference.

The heat recovery performance was similar to the first year of monitoring. The values in Figure 5.2.8 indicate an average efficiency of 45 percent and an effectiveness of 85 percent. The results of the ORF test indicated an effectiveness of about 93 percent. Apparently the ambient temperature had little effect on exhaust flow efficiency as shown in Figures 5.2.9 and 5.2.10. There was no defrost in this HRV. The Kingston air changer unit, in comparison, showed more temperature dependency, and slightly better heat recovery performance.

5.2.4 Nutech Lifebreath 250 in Erin Mills

The Erin Mills HRV was under the operation of a timer, with the unit on for 14 hours (6 pm to 8 am), and off for the balance of the 24 hour cycle. The average flows, as seen in Figure 5.2.11, are therefore lower than they would be if kept in continuous operation. Under continuous operation the flows would have been approximately 70 percent greater. The flows were also unbalanced as the figure illustrates.

On October 9, 1986, the supply duct grille was cleaned and the flow subsequently increased when compared with the preceding month. During December, January and March, 1987, the flows were on high speed for 50 percent of the day. Defrost occurred for only a few days in January, February and March.

The efficiencies and the effectiveness of the HRV are shown in Figure 5.2.12. The heat recovery performance is relatively low when compared to the Air Changer unit. The Lifebreath unit has an average heat recovery efficiency of 28 percent, and an effectiveness of 60 percent. The ORF test results indicate an effectiveness of 67 percent.

As seen in Figures 5.2.13 and 5.2.14, the flow and the efficiency fluctuated independently of the ambient temperature.

Summer cooling occurred on certain days in July and August. The conditions were similar to those experienced by the Kingston Air Changer unit.

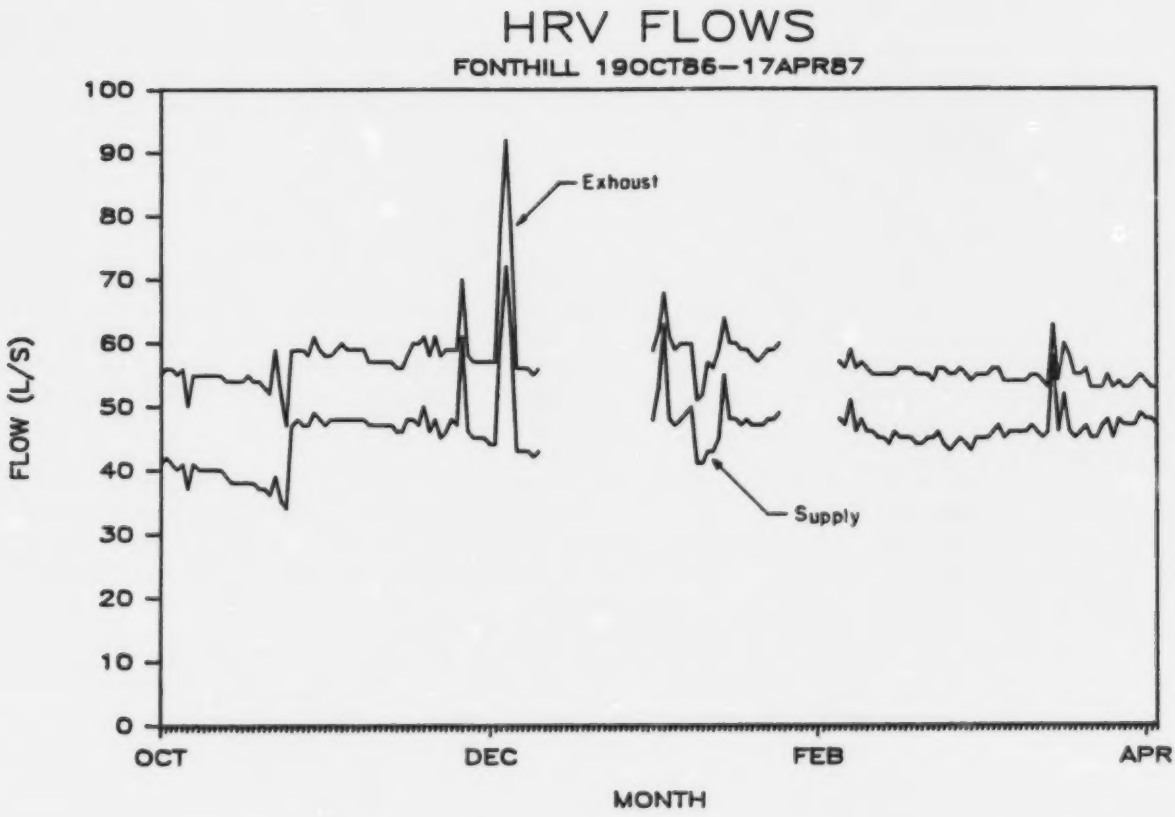

HRV FLOWS
FONTHILL 19OCT86–17APR87
100
90
80
70
60
50
40
30
20
10
0
FLOW (L/S)
Exhoust
Supply
OCT
DEC
FEB
APR
MONTH

Figure 5.2.7

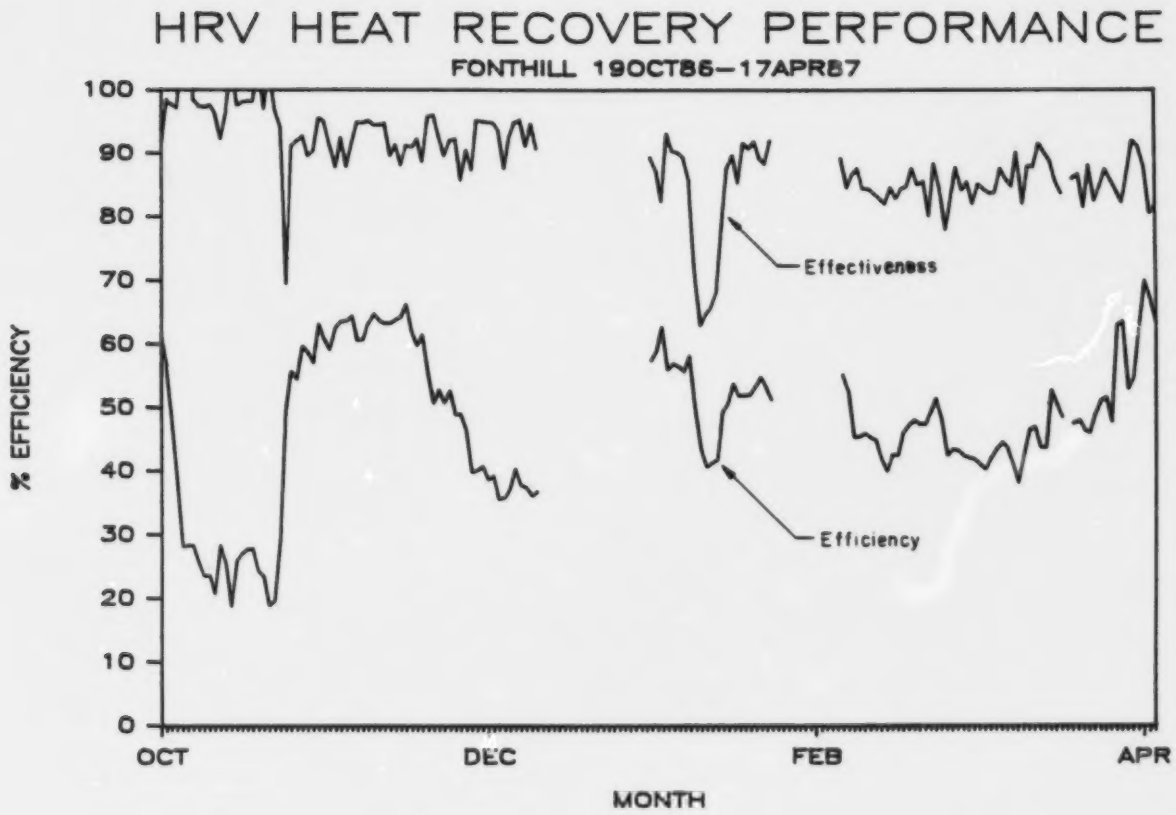

HRV HEAT RECOVERY PERFORMANCE
FONTHILL 19OCT86–17APR87
% EFFICIENCY
100
90
80
70
60
50
40
30
20
10
0
OCT
DEC
FEB
APR
MONTH
Effectiveness
Efficiency

Figure 5.2.8

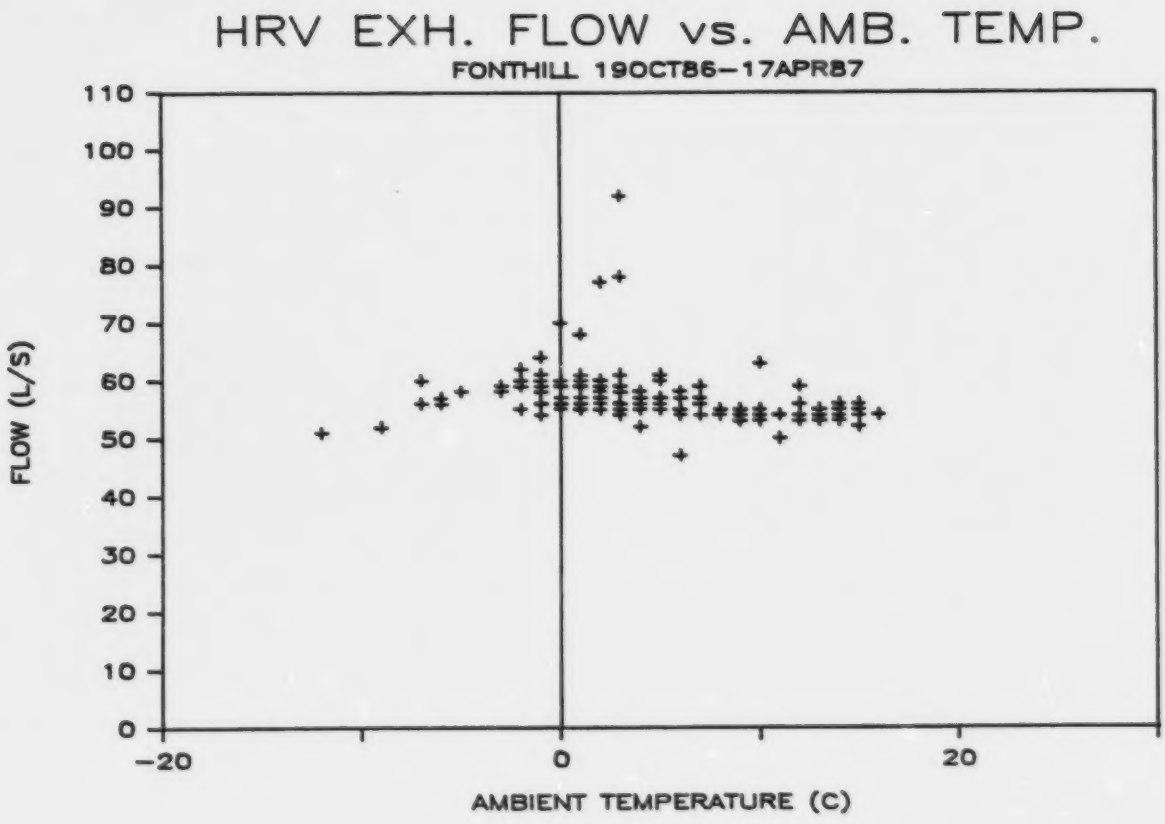

HRV EXH. FLOW vs. AMB. TEMP.
FONTHILL 19OCT86–17APR87
FLOW (L/S)
110
100
90
80
70
60
50
40
30
20
10
0
–20
0
20
AMBIENT TEMPERATURE (C)

Figure 5.2.9

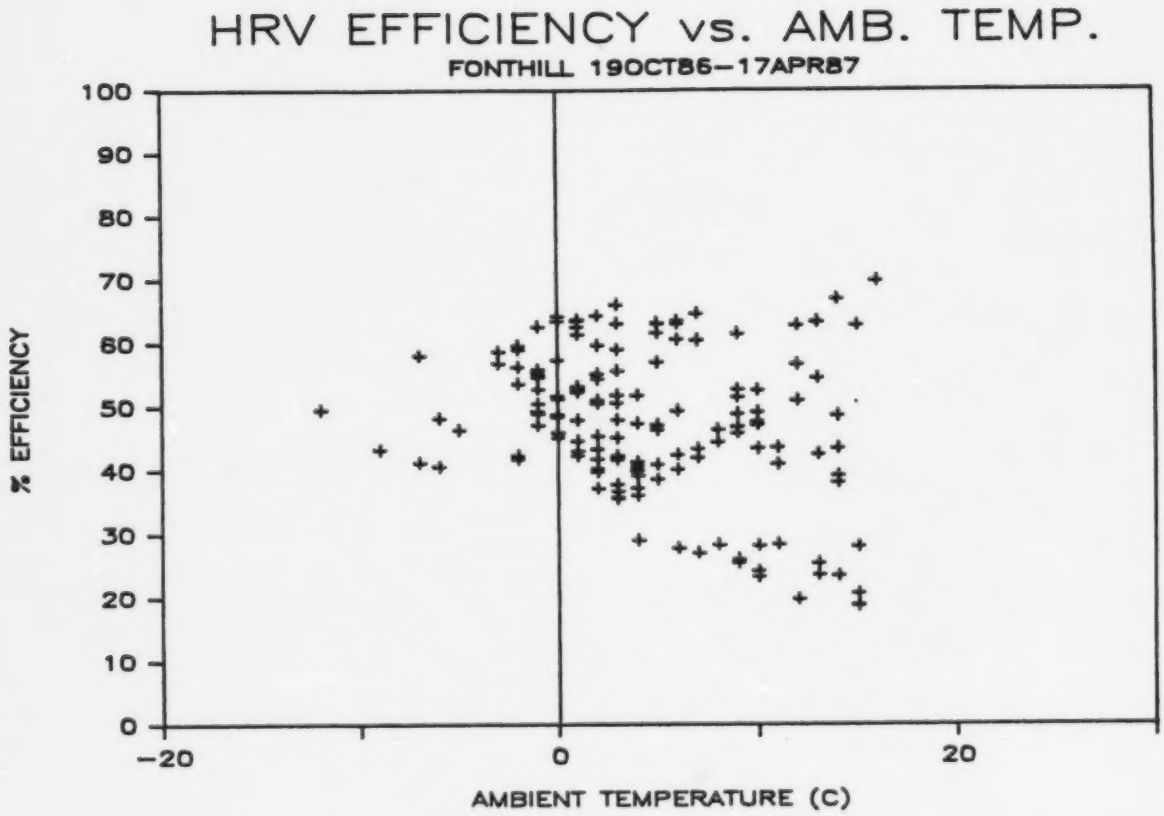

HRV EFFICIENCY vs. AMB. TEMP.
FONTHILL 19OCT86–17APR87
% EFFICIENCY
100
90
80
70
60
50
40
30
20
10
0
–20
0
20
AMBIENT TEMPERATURE (C)

Figure 5.2.10

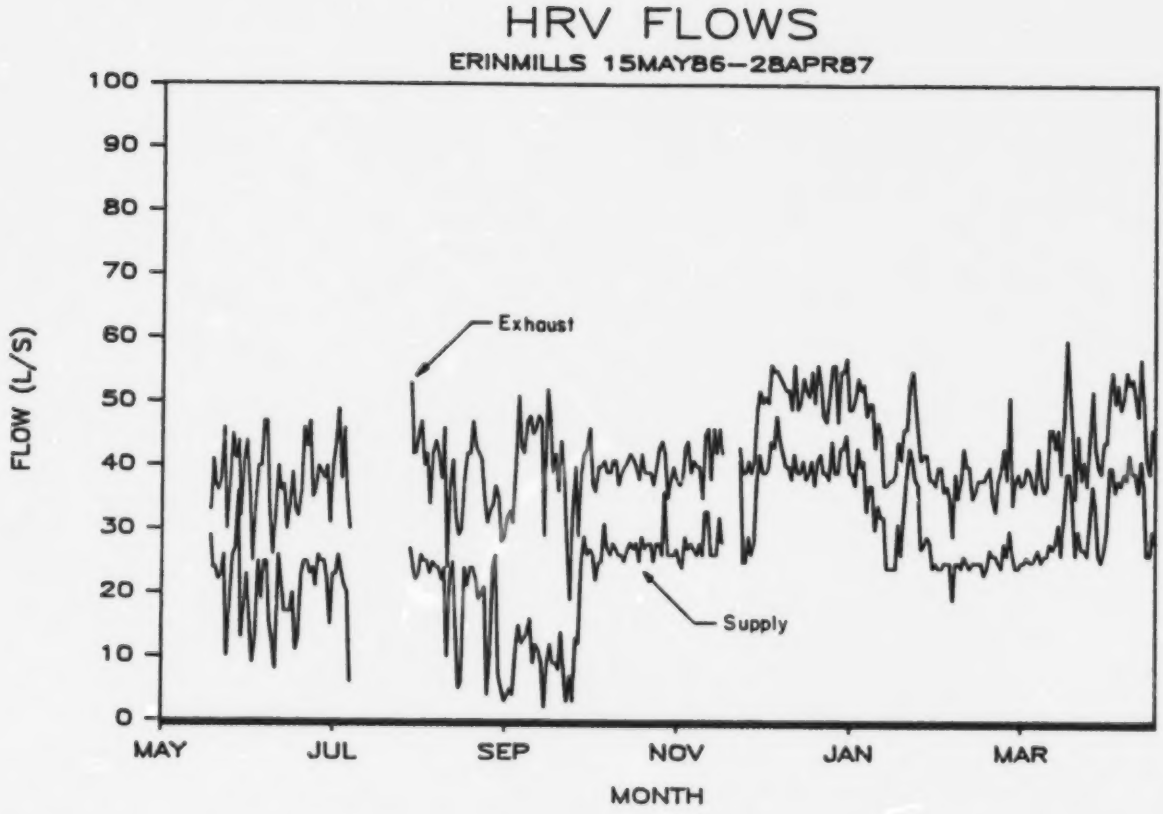

HRV FLOWS
ERINMILLS 15MAY86–28APR87
FLOW (L/S)
100
90
80
70
60
50
40
30
20
10
0
Exhaust
Supply
MAY
JUL
SEP
NOV
JAN
MAR
MONTH

Figure 5.2.11

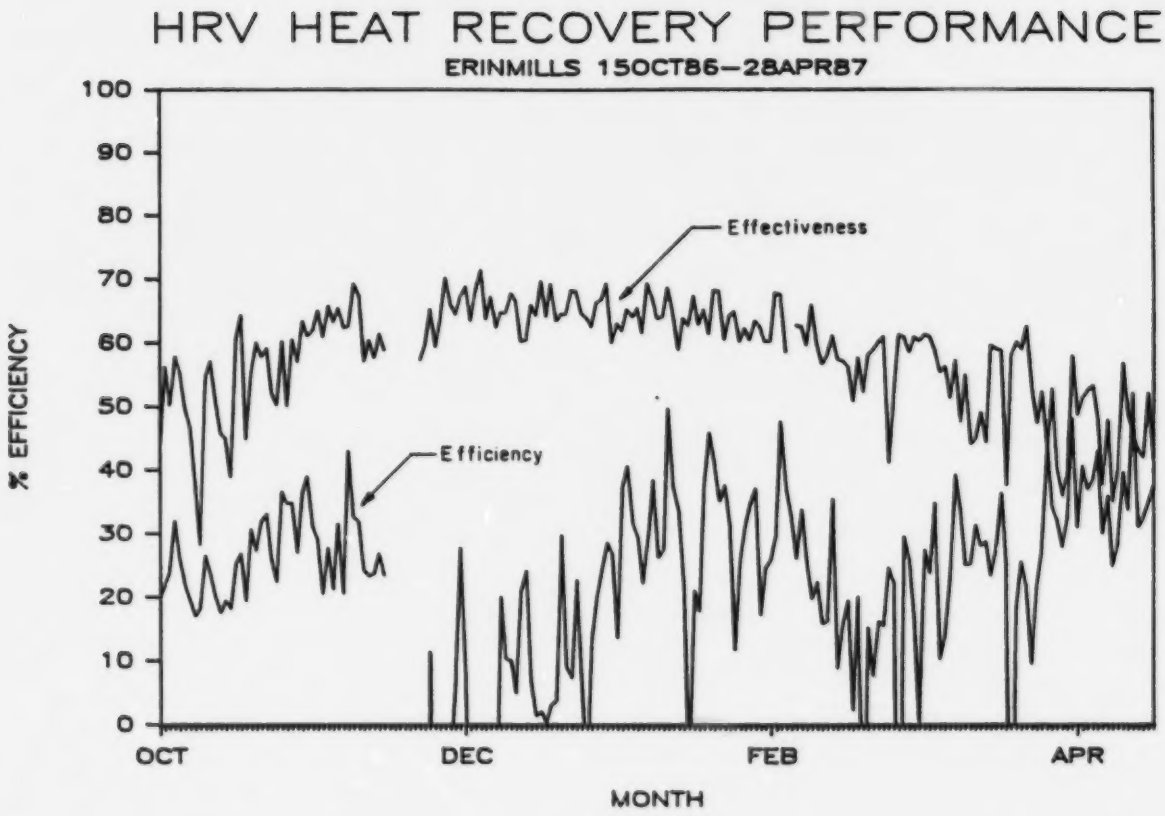

HRV HEAT RECOVERY PERFORMANCE
ERINMILLS 15OCT86–28APR87
% EFFICIENCY
100
90
80
70
60
50
40
30
20
10
0
Effectiveness
Efficiency
OCT
DEC
FEB
APR
MONTH

Figure 5.2.12

5.3 Temperature and Humidity Control

This section deals with the relationship between the HRV operation and house humidities and temperatures. In addition, the effect of furnace operation on the HRV flows is considered.

In order to assess comfort levels in the houses monitored in detail, humidities were recorded in three locations and temperatures in eight locations. Two of the temperatures were recorded in warm air supply ducts.

An analysis of the data collected at the various locations was undertaken to determine whether:

- the cool HRV supply air during the winter cooled the distributed supply air to the rooms in the house;
- the furnace had sufficient capacity to heat the house and, if it was running at full capacity, the extent of any temperature drop;
- significant temperature or humidity stratifications developed in the houses;
- periods of relatively high humidities were encountered in the house, and whether HRV high speed operation was effective in reducing or stabilizing these peak periods;
- furnace operation affected HRV flows.

The supply air temperature to a room rarely fell below the average room temperature. The largest temperature difference observed was in Fonthill during high speed operation. In this case the maximum temperature difference observed was 3°C.

Figures 5.3.1 to 5.3.4 show the daily percentage of furnace operating time. In the Kingston house, the furnace operated for a maximum of approximately 70 percent of any day. In all other cases, the peak heating requirements of the house were near or exceeded the furnace capacity.

In the Fonthill house, there were a significant number of days where the furnace capacity was exceeded by demand. An analysis, however, of indoor temperatures during the months of January and February in Fonthill showed no temperature drops during periods of long furnace activity.

The Erin Mills house went through the entire heating season without one day of 100 percent furnace "on" time. This house, therefore, and probably the other R-2000 houses in Erin Mills, were not "under-heated" by their furnaces. The complaints about cold rooms by some Erin Mills homeowners could be attributed to problems of distribution of heat and not to problems of supply of heat.

In assessing temperature and humidity stratification, temperatures were typically not found to differ by more than a few degrees Celsius, and humidities not to differ by more than a few percent between monitoring locations in the houses. As examples, warmest day and coldest day humidity

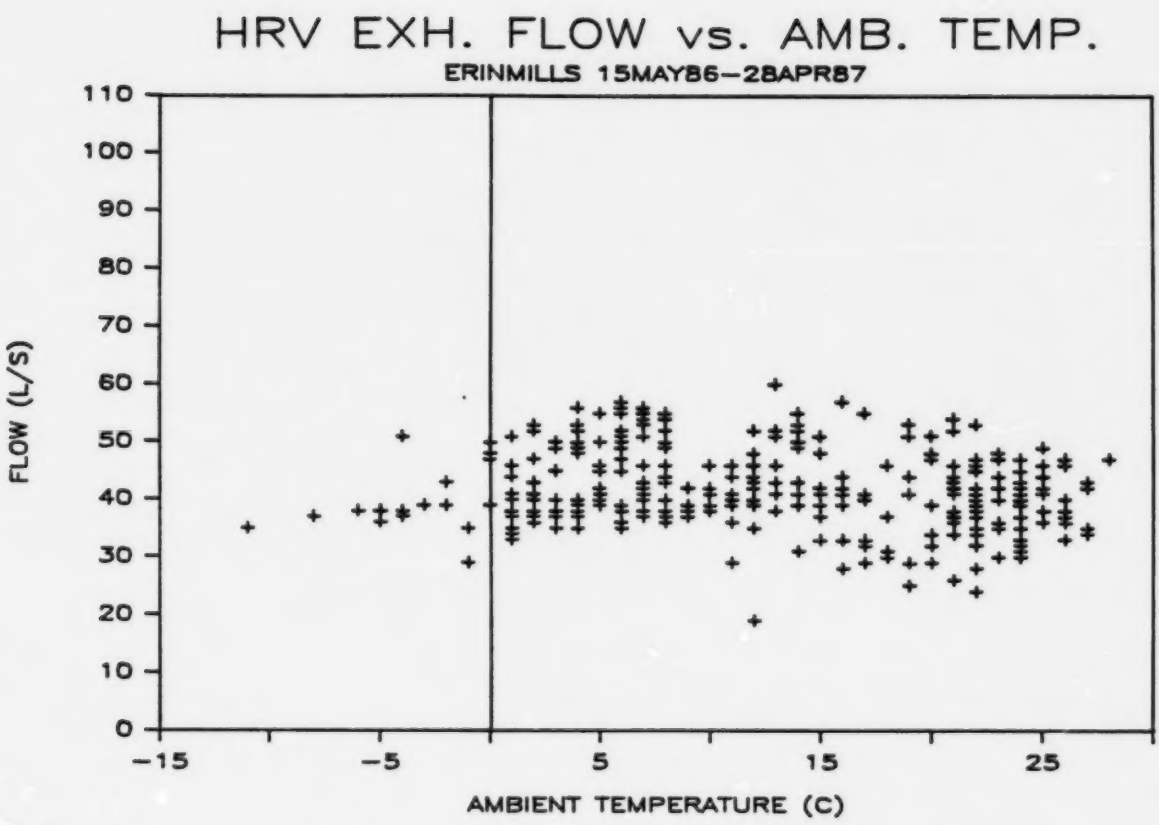

HRV EXH. FLOW vs. AMB. TEMP.
ERINMILLS 15MAY86–28APR87
FLOW (L/S)
110
100
90
80
70
60
50
40
30
20
10
0
−15
−5
5
15
25
AMBIENT TEMPERATURE (C)

Figure 5.2.13

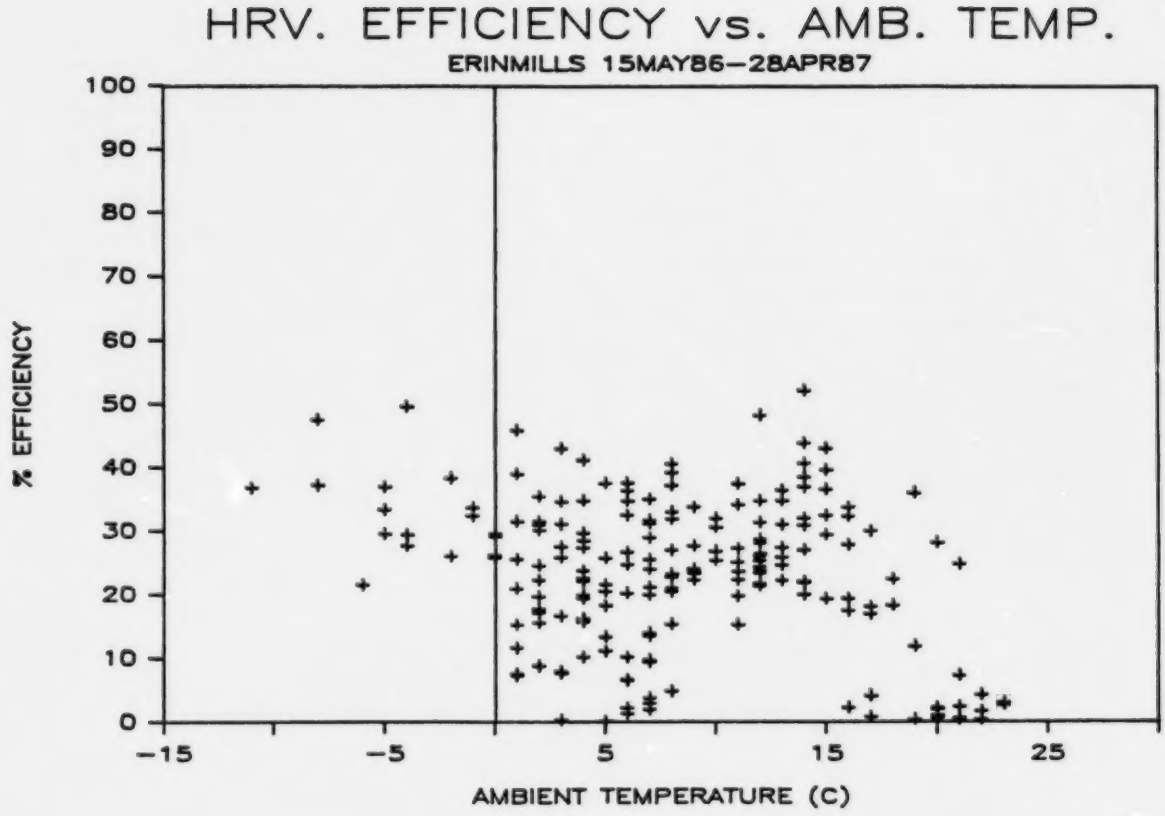

HRV. EFFICIENCY vs. AMB. TEMP.
ERINMILLS 15MAY86–28APR87
% EFFICIENCY
100
90
80
70
60
50
40
30
20
10
0
−15
−5
5
15
25
AMBIENT TEMPERATURE (C)

Figure 5.2.14

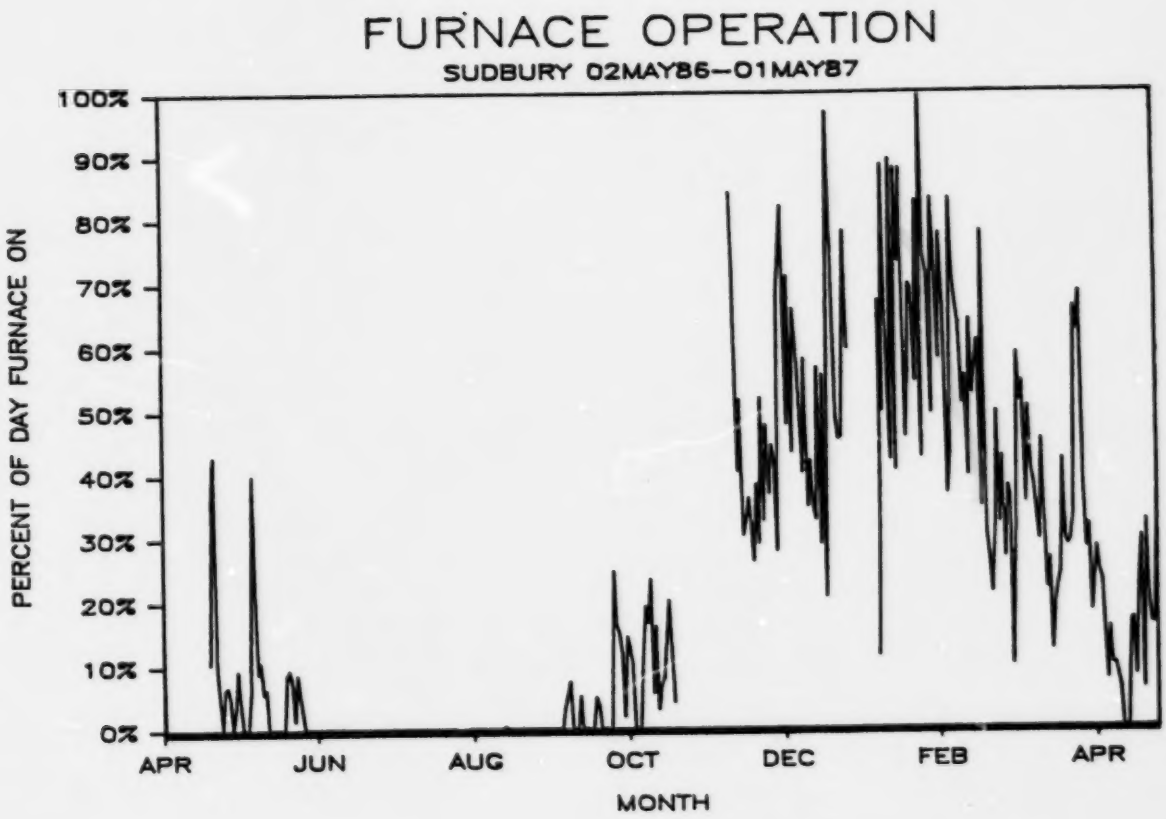

FURNACE OPERATION
SUDBURY 02MAY86–01MAY87
PERCENT OF DAY FURNACE ON
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
APR
JUN
AUG
OCT
DEC
FEB
APR
MONTH

Figure 5.3.1

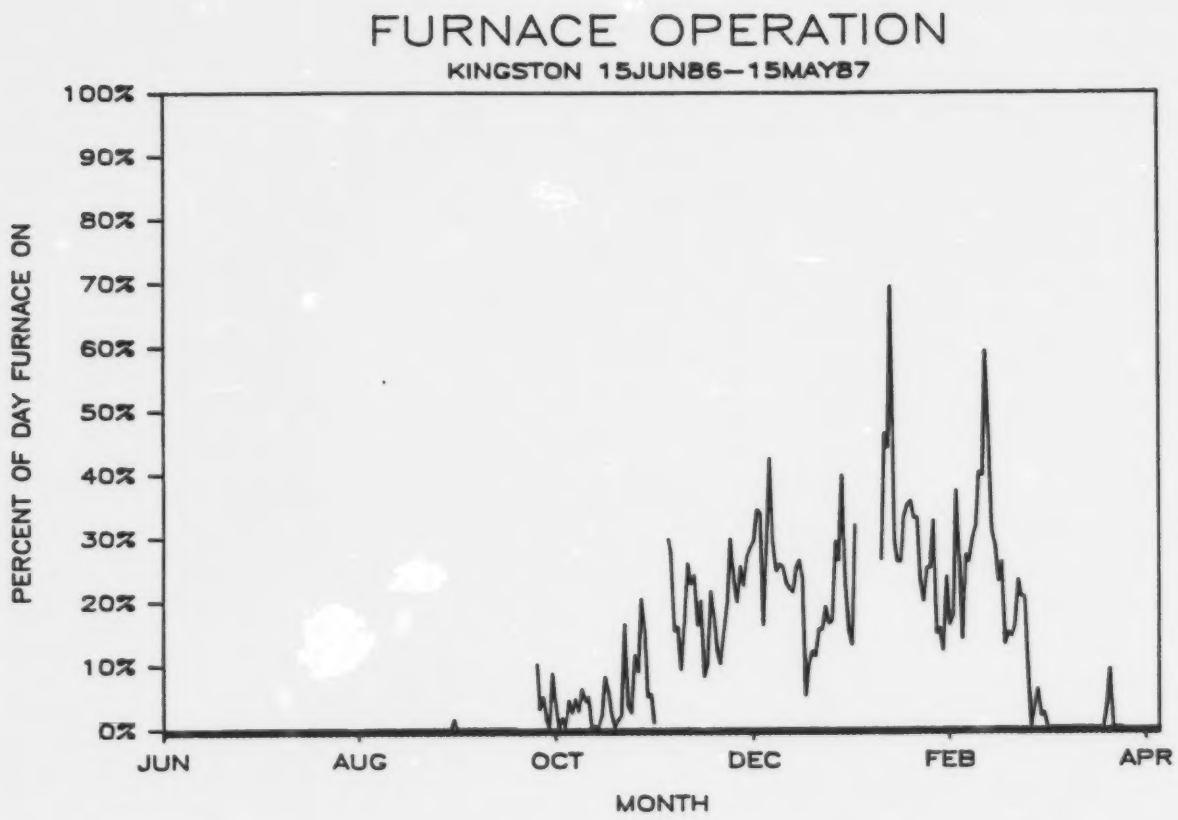

FURNACE OPERATION
KINGSTON 15JUN86–15MAY87
PERCENT OF DAY FURNACE ON
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
JUN
AUG
OCT
DEC
FEB
APR
MONTH

Figure 5.3.2

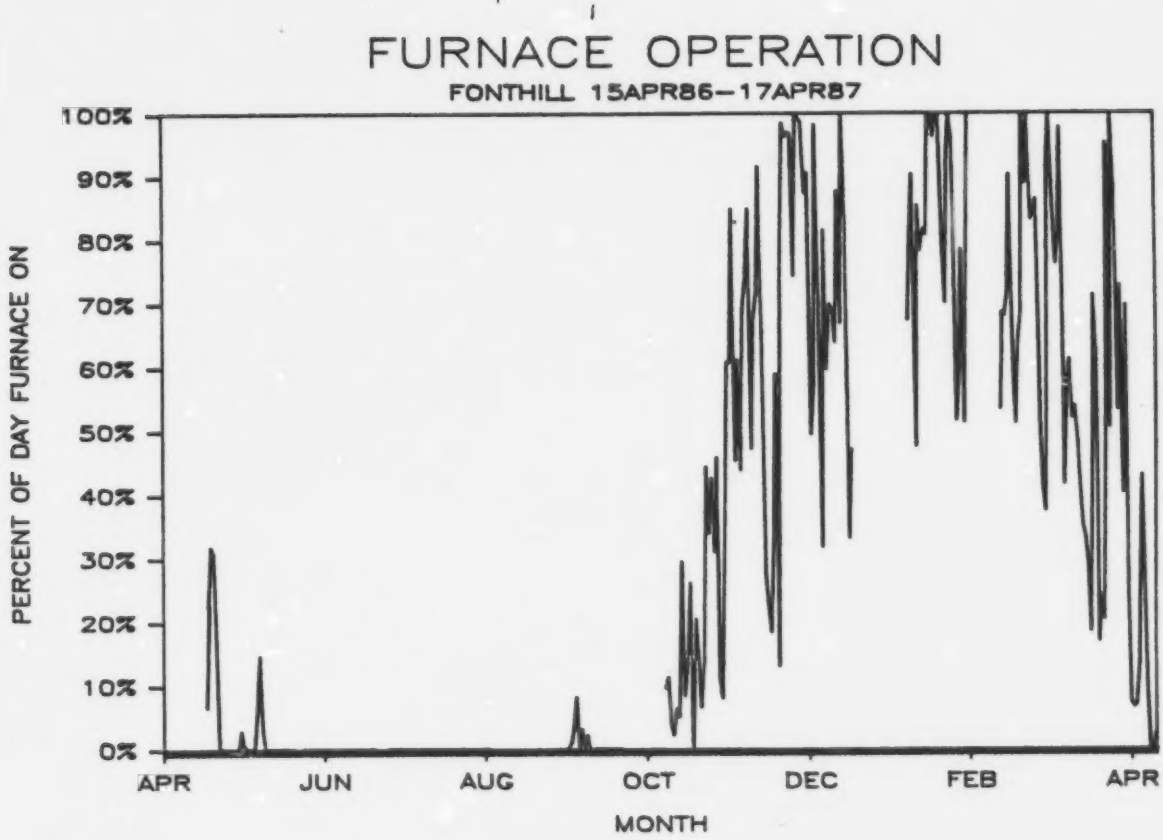

FURNACE OPERATION
FONTHILL 15APR86–17APR87
PERCENT OF DAY FURNACE ON
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
APR
JUN
AUG
OCT
DEC
FEB
APR
MONTH

Figure 5.3.3

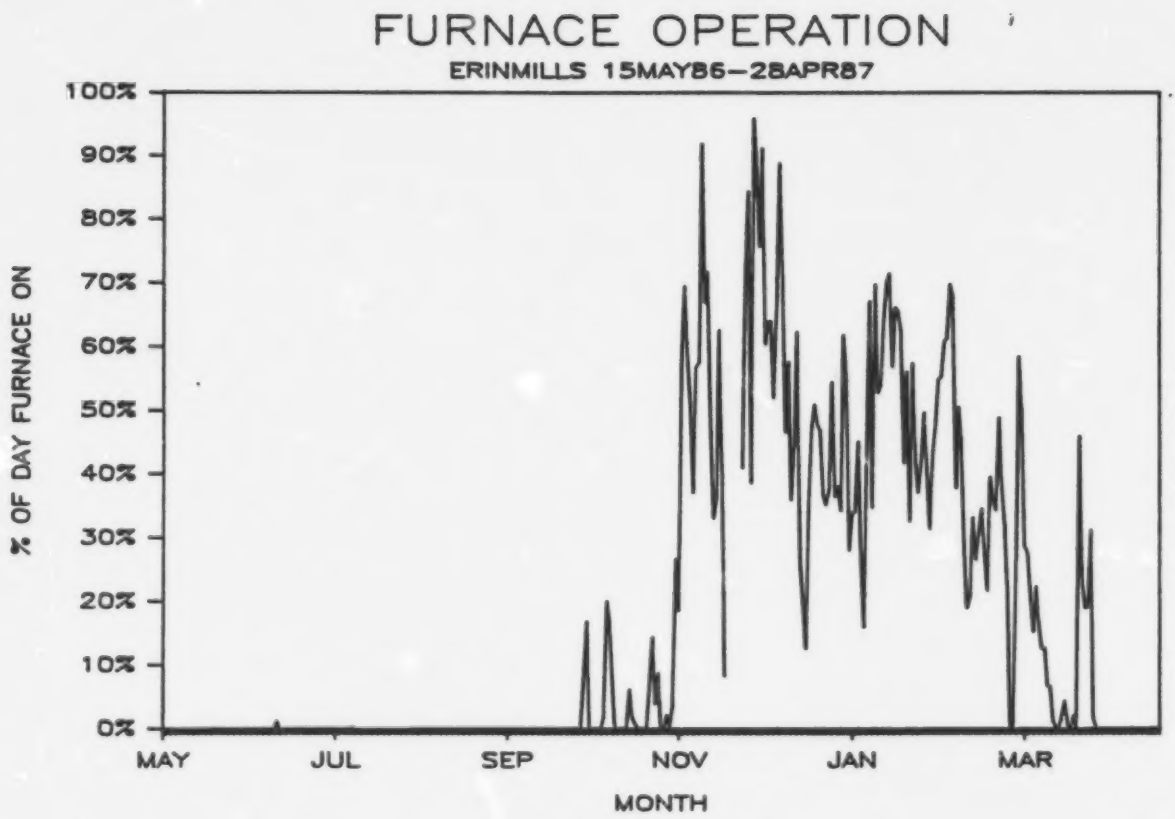

FURNACE OPERATION
ERINMILLS 15MAY86–28APR87
% OF DAY FURNACE ON
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
MAY
JUL
SEP
NOV
JAN
MAR
MONTH

Figure 5.3.4

and temperature profiles for Fonthill are included as Figures 5.3.5 to 5.3.8. These profiles illustrate that the distribution of heat in the house was relatively uniform. The data for the houses in the other locations indicate similar trends.

Figure 5.3.9 shows the annual humidity trends for the Fonthill location. Figure 5.3.10 shows the annual temperature trends. The graphs present the average of the three values monitored in the house. A similar trend occurred in all four locations.

In all cases, the winter house humidities were maintained below the winter humidistat set points.

A detailed examination was made of the HRV flows and furnace operation for the January and February period in Kingston to identify any possible correlations. No correlations were found between the operation of the furnace and HRV flows, the periods of high speed operation, or the defrost cycles.

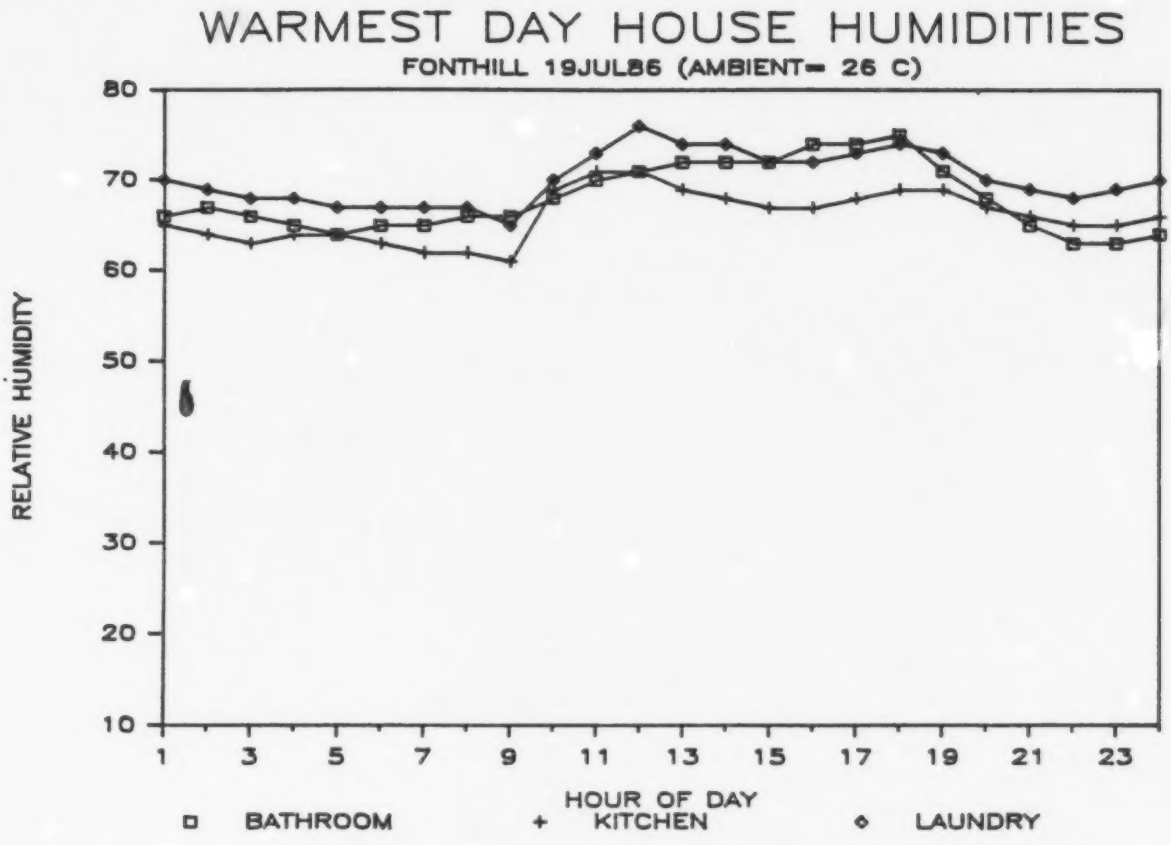

WARMEST DAY HOUSE HUMIDITIES
FONTHILL 19JUL86 (AMBIENT= 26 C)
RELATIVE HUMIDITY
80
70
60
50
40
30
20
10
1
3
5
7
9
11
13
15
17
19
21
23
HOUR OF DAY
BATHROOM
KITCHEN
LAUNDRY

Figure 5.3.5

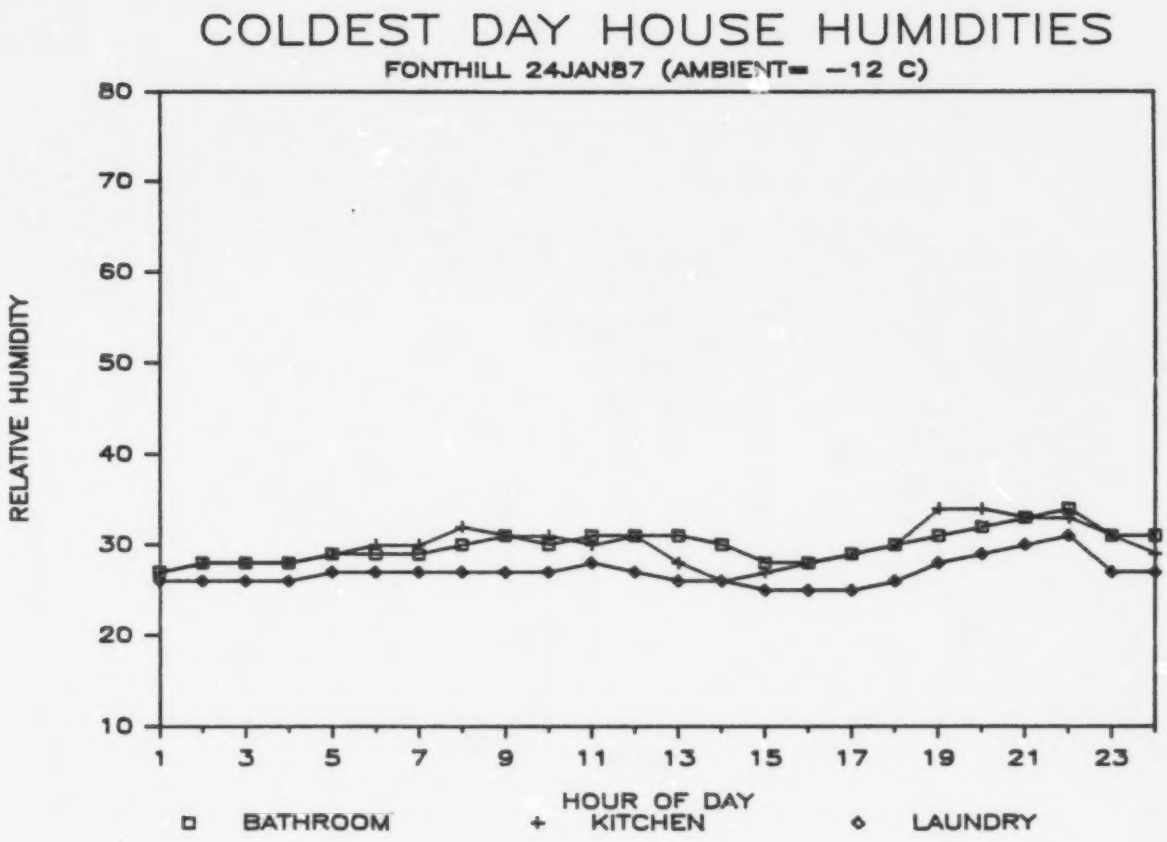

COLDEST DAY HOUSE HUMIDITIES
FONTHILL 24JAN87 (AMBIENT= -12 C)
RELATIVE HUMIDITY
80
70
60
50
40
30
20
10
1
3
5
7
9
11
13
15
17
19
21
23
HOUR OF DAY
BATHROOM
KITCHEN
LAUNDRY

Figure 5.3.6

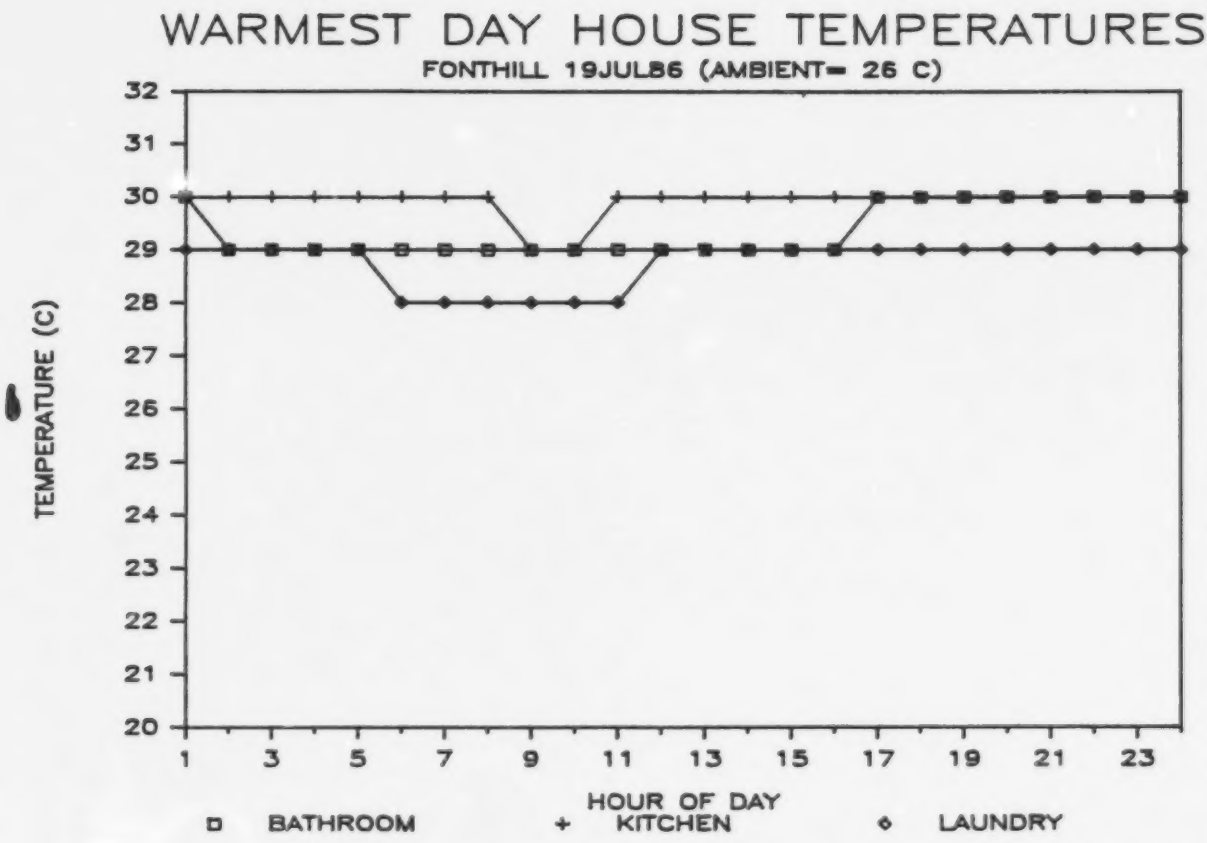

WARMEST DAY HOUSE TEMPERATURES
FONTHILL 19JUL86 (AMBIENT= 26 C)
TEMPERATURE (C)
32
31
30
29
28
27
26
25
24
23
22
21
20
1
3
5
7
9
11
13
15
17
19
21
23
HOUR OF DAY
BATHROOM
KITCHEN
LAUNDRY

Figure 5.3.7

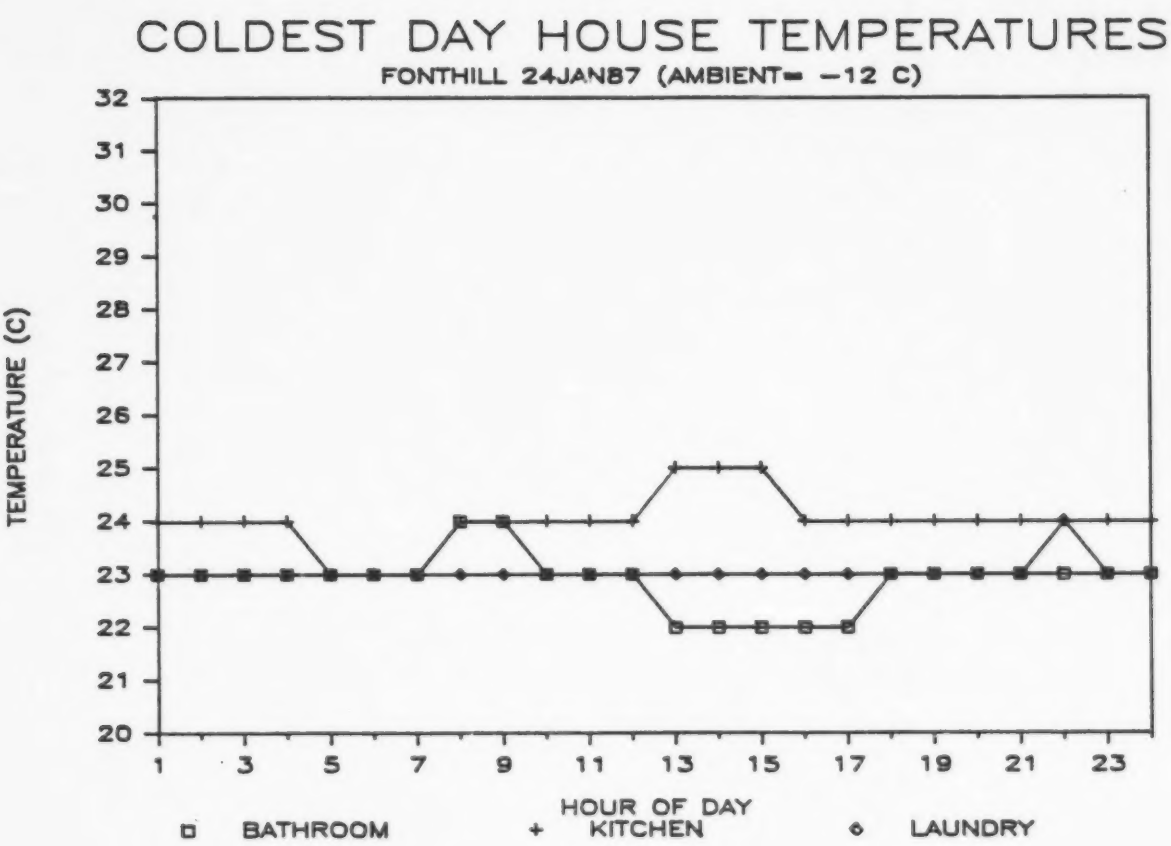

COLDEST DAY HOUSE TEMPERATURES
FONTHILL 24JAN87 (AMBIENT= -12 C)
TEMPERATURE (C)
32
31
30
29
28
27
26
25
24
23
22
21
20
1
3
5
7
9
11
13
15
17
19
21
23
HOUR OF DAY
BATHROOM
KITCHEN
LAUNDRY

Figure 5.3.8

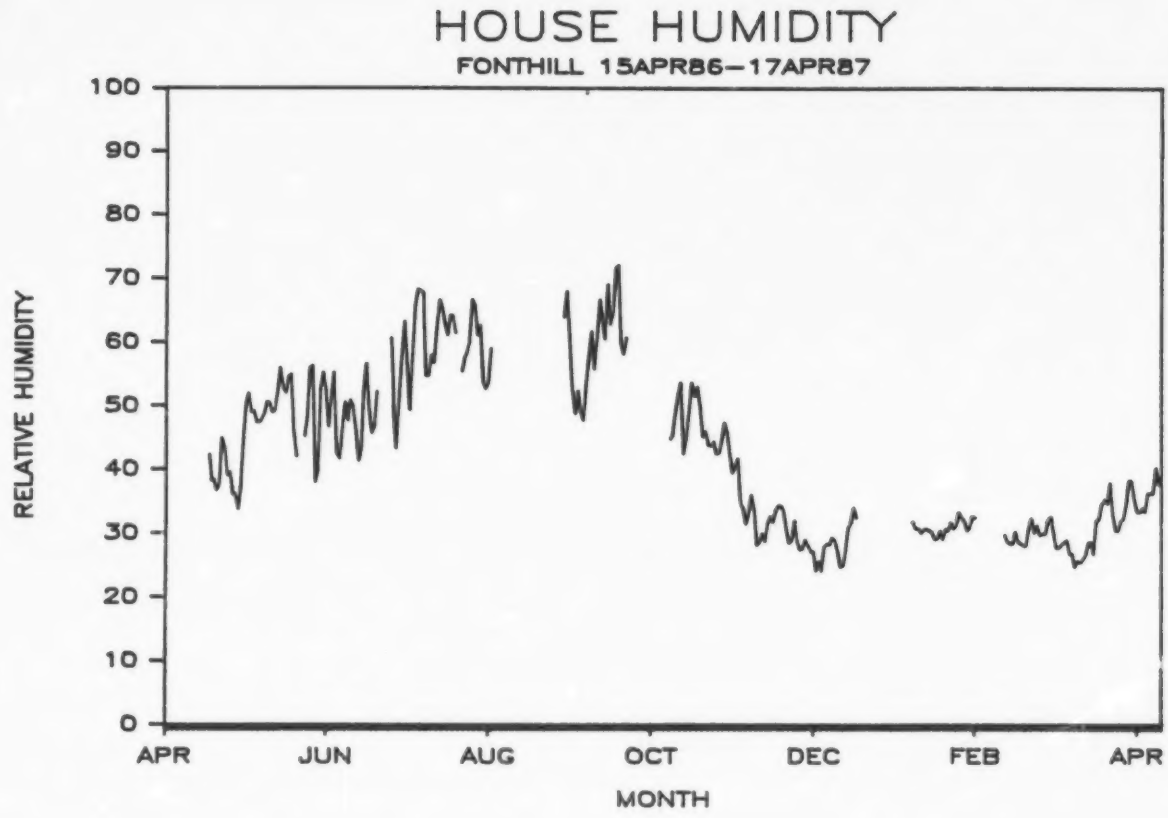

HOUSE HUMIDITY
FONTHILL 15APR86–17APR87
RELATIVE HUMIDITY
100
90
80
70
60
50
40
30
20
10
0
APR
JUN
AUG
OCT
DEC
FEB
APR
MONTH

Figure 5.3.9

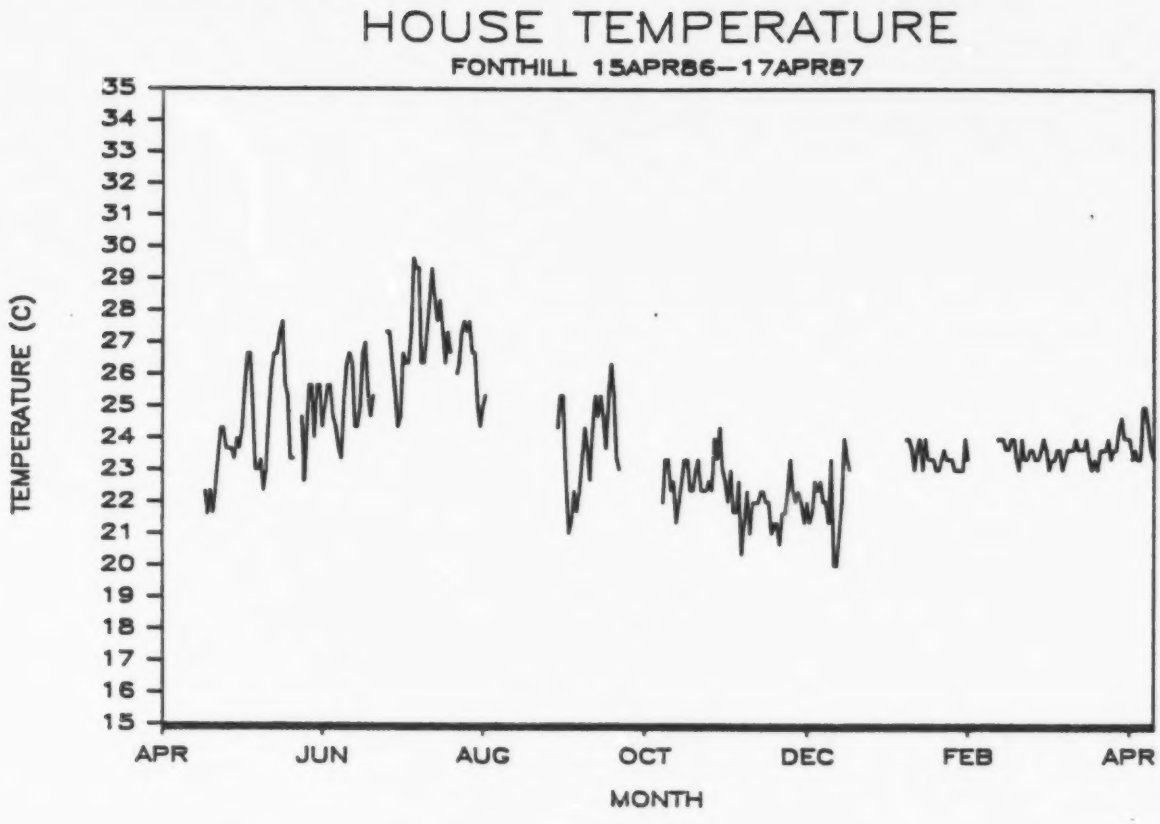

HOUSE TEMPERATURE
FONTHILL 15APR86–17APR87
TEMPERATURE (C)
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
APR
JUN
AUG
OCT
DEC
FEB
APR
MONTH

Figure 5.3.10

6.0 HOMEOWNER FEEDBACK

6.1 Formal Questionnaire Response

In order to ensure the compatibility of homeowner data with the Federal R-2000 program, the general Federal R-2000 questionnaire forms were used throughout this monitoring program. Two specific homeowner questionnaires are available for R-2000 homeowners. The first questionnaire is an initial survey of the homeowner's profile and concerns and expectations related to the R-2000 home. The second is a follow-up questionnaire used to document ongoing concerns and changes in attitude toward the R-2000 home. A sample questionnaire was included in the 1986 monitoring report.

In order for this information to be useful, it must be collected from a large sample of R-2000 occupants and tracked over a significant period of time. The only data available for this specific monitoring program consists of the data for the twenty seven R-2000 homes, with three follow-up questionnaires.

It is not easy to judge the degree to which the occupants of these twenty seven houses are typical of the average Ontario resident. Because of the nature of the R-2000 program, it is likely that these people are, on average, more concerned with housing quality issues and energy efficiency.

From the formal questionnaires, it is difficult to draw many significant conclusions, however, Table 6.1.1 illustrates one major area of concern. This table relates, on a percentage basis, the number of occupants who state they would consider buying another R-2000 house.

In September of 1985, one hundred percent of the occupants in all four communities stated that they would consider the purchase of another R-2000 home.

After a substantial portion of the heating season had passed, this percentage had dropped in Sudbury by twenty percent, in Fonthill by sixty percent, and in Erin Mills by seventy percent. Only in Kingston did all five occupants in the sample state that they would still consider buying another R-2000 home.

Since the spring of 1986 the percentage of homeowners who would consider buying another R-2000 house has remained fairly stable. During the period, there was a change in ownership of approximately 35 percent of the original twenty two houses in the sample. The changes in homeowner attitudes towards their R-2000 houses was directly related to the number of complaints and specific concerns put forward by the homeowners in the various communities. In the case of Erin Mills, unrealistic expectations created by unknowledgeable sales staff influenced homeowner dissatisfaction.

Table 6.1.1 **PERCENTAGE OF OCCUPANTS WHO WOULD BUY ANOTHER R-2000 HOME**

	September 1985	March 1986	September 1986	March 1987
SUDBURY	100	80	100	80
KINGSTON	100	100	100	100
FONTHILL	100	40	40	40
ERIN MILLS Phase I	100	30	0	30
ERIN MILLS Phase II	-	-	-	20

6.2 Specific Concerns

In addition to the basic R-2000 questionnaire, supplemental questionnaires were produced to ask homeowners to describe specific observations about their R-2000 houses.

The method of questioning prompted occupants to give answers of yes, they had observed a specific problem, or no, they had not observed a specific problem. In addition, if a yes answer was given, the occupant was asked to quantify the severity of the problem, as significant, or minor.

From these responses, Table 6.2.1 was generated. It lists the specific problems expressed during the interviews with each occupant. These questions were asked during both the 1985/1986 heating season and the 1986/1987 heating season. The listing in the table is in the descending order of the frequency of occurrence in the 1985/1986 sample.

A comparison of the responses from two years indicates an increase in the concerns over energy costs, drafts and high humidity levels, and a decrease in concern with dust and air distribution.

It should be noted that the number of concerns with high humidity and dryness are almost equal.

The very significant decrease in the concerns with dust are likely related to the completion of landscaping in the neighborhood of the monitored houses. The decrease in the complaints related to air distribution is related to balancing work carried out by the contractor and more careful attention to the cleaning of furnace air filters by the homeowners.

It should also be noted that the total number of complaints has decreased by more than 10 percent, in spite of an increase in the number of houses being monitored by more than 20 percent.

TABLE 6.2.1 **SPECIFIC OCCUPANT OBSERVATIONS**

	1985 - 1986		1986 - 1987	
	Significant Problem	Minor Problem	Significant Problem	Minor Problem
Dust	9	3	5	0
Air Distribution	8	0	4	2
Dryness	5	3	4	1
Furnace Noise	4	2	3	1
Stuffiness	3	1	1	1
Energy Cost	3	0	4	1
High Humidity	1	2	5	2
Drafts	1	0	4	0
Odours	1	0	2	1

7.0 CONCLUSIONS AND RECOMMENDATIONS

This report has been generated after the first complete year of monitoring data has been obtained. With this data, pertinent conclusions can be drawn on the performance of the original twenty two houses in the areas of building envelope tightness, energy performance, air quality and potential building envelope problems. Insufficient data is currently available on the operation of the Phase II Erin Mills units added to the monitoring program in early 1987.
Significant stabilization of the loosening of the building envelopes has taken place with minor decreases in air leakage in some instances. The tightening of the envelopes generally correlates with remedial work done by either the building contractor or the homeowner.

Energy consumption varies greatly from one community to another, as was reported in the previous years' report. No significant changes in the energy consumption figures have been observed.

The only air quality area presenting any degree of concern is that of formaldehyde. A significant proportion of the houses being monitored exceed, on average, the proposed Health and Welfare Canada long-term formaldehyde levels. In all houses with a complete year of formaldehyde monitoring, there were observations of formaldehyde levels in excess of the proposed Health and Welfare Guidelines. Summer data is not yet available for the five Erin Mills Phase II units.

Repeat building fabric investigations undertaken using thermographic scanning techniques observed no instances of moisture accumulation in the structures. Detailed inspections revealed no areas of concern relating to the potential for deterioration in the fabric of the buildings.

After an initial drop, the satisfaction level expressed by homeowners in terms of their desire to buy another R-2000 house, has stabilized. There has been no marked increase, however, in the stated satisfaction level, although specific complaints have decreased significantly over the past year of monitoring.

The heat recovery ventilators appear to be performing basically as predicted by the laboratory test work required for certification. However, notable operational problems are still being experienced with several of the heat recovery ventilators. Of particular concern has been the Nutone unit installed in Sudbury, where reliable operation for the winter months has not been attained.

The heat recovery ventilator systems, except for those installed in the Erin Mills units, are being upgraded in order to meet the current continuous and peak flow requirements. This upgrading will allow for the detailed investigation of the impact of the improved ventilation systems on the air quality in these units in the third year of the monitoring program. The original ventilation systems were installed to meet the same ventilation standard as are currently in effect, however, procedures were not in place for the adequate training of installers and the inspection of finished installations. After the upgrading of the ventilation systems, a comparison of

the test results will be extremely valuable in assessing the importance of the current training requirements and inspection procedures.

It is recommended that the air-tightness testing of these units be continued, in order that the medium-term stability of the building envelopes can be assessed. A third year of directly comparable tests will assist in the projection of the longer term air leakage characteristics of these types of units.

The Erin Mills townhouse development is the first major tract-built R-2000 development in Canada. Significant problems were encountered in the construction of the first phase of eighty two units. Phase II of the Erin Mills development involved one hundred and twenty units. Although the development is essentially the same as Phase I, a number of changes have been included as a result of the problem areas noted in Phase I. The results of the monitoring of Phase II will be valuable in assessing the difficulties of meeting the R-2000 standards in a tract-built environment and in assessing the learning curve of a major tract-builder.

In order to meet the basic objectives of the overall monitoring program, it is recommended that the program be carried out through a third heating season essentially unchanged from the previous years. The only major deletion recommended is in the undertaking of detailed thermographic investigations. This work is extremely costly and not likely to yield more meaningful information than has already been obtained in the first two years of investigations.

APPENDIX A

HOUSE PROFILES

HOUSE A, SUDBURY, ONTARIO

Type of House: Side Split - Full Basement

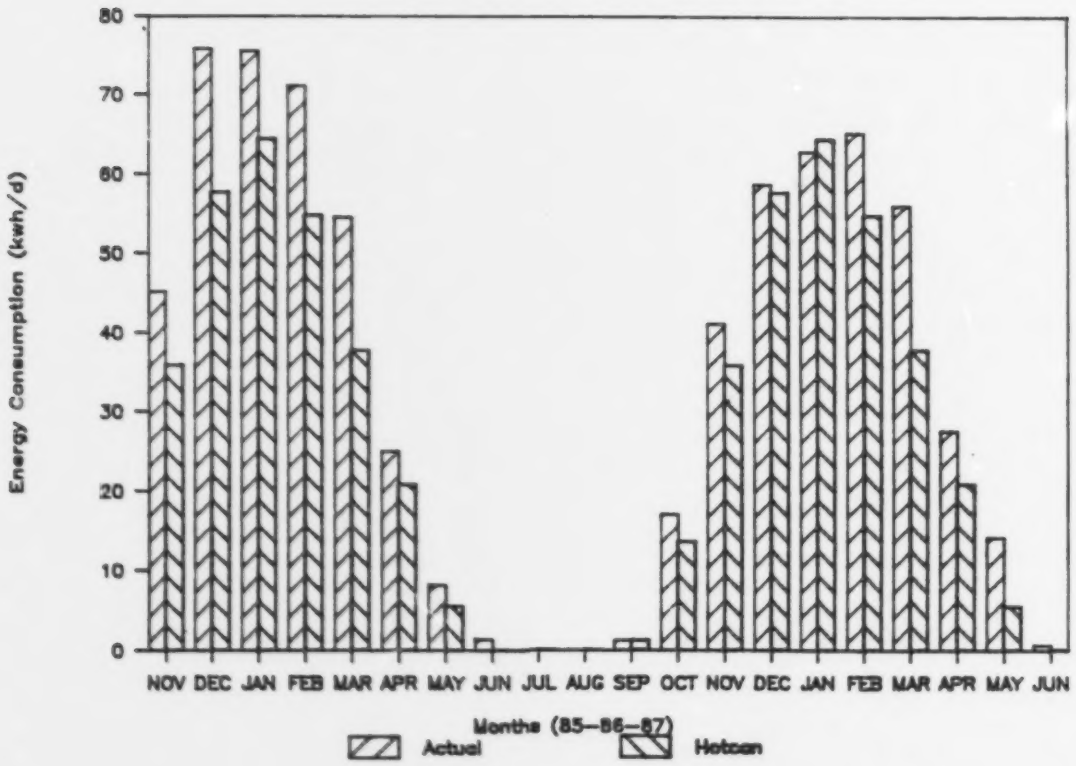
Appliances (Make & Type)
- Furnace: Electric baseboard
- DHW Heater: John Wood - electric (40 gallon)
- Fireplace(s): One
- Air Conditioning: No

Floor Area: 199.2 m^2

Homeowner Profile

Age of owner:	18 - 30	Age of Spouse:	31 - 45
Number of occupants:		Adults: 2	Children: 3
Number home during the day:		Adults: 1	Children: 2

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 8,809 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 10,322 kWh

HOUSE B, SUDBURY, ONTARIO

Type of House: Bungalow - Full basement

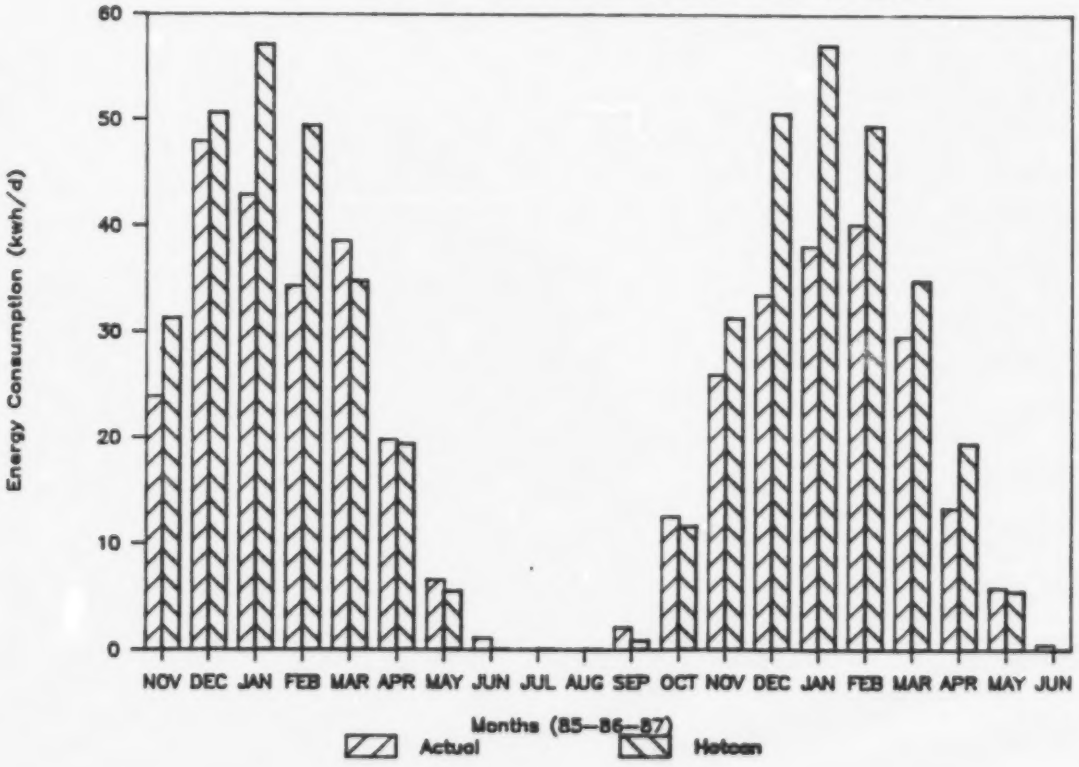
Appliances (Make & Type)
- Furnace: Olsen Minimax - natural gas
- DHW Heater: Rheem - electric
- Fireplace(s): No
- Air Conditioning: No

Floor Area: 199.2 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 18 - 30		
Number of occupants:	Adults: 2	Children: 3	
Number home during the day:	Adults: 1	Children: 2	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 7,866 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 6,161 kWh

HOUSE C, SUDBURY, ONTARIO

Type of House: Bungalow - Full Basement

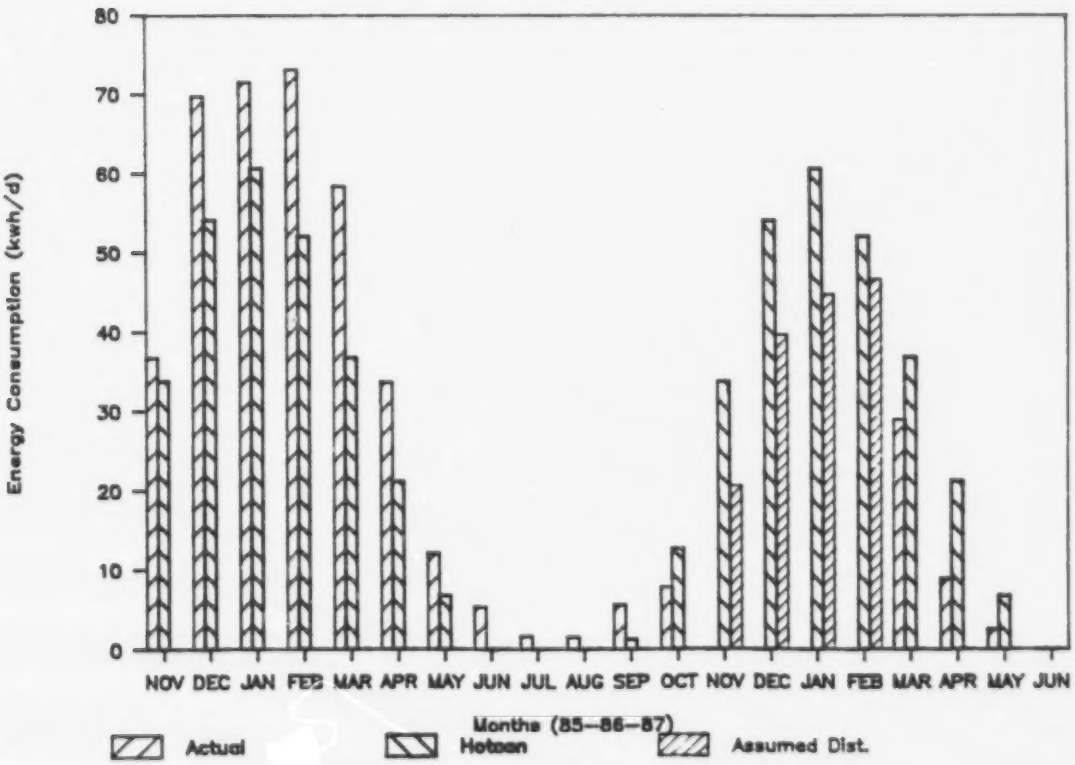
Appliances (Make & Type)
- Furnace: Olsen Minimax - natural gas
- DHW Heater: Rheem - natural gas
- Fireplace(s): No
- Air Conditioning: No

Floor Area: 199.2 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 2	
Number home during the day:	Adults: 1	Children: 1	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 8,432 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 6,735 kWh

HOUSE D, SUDBURY, ONTARIO

Type of House: Side Split - Full basement

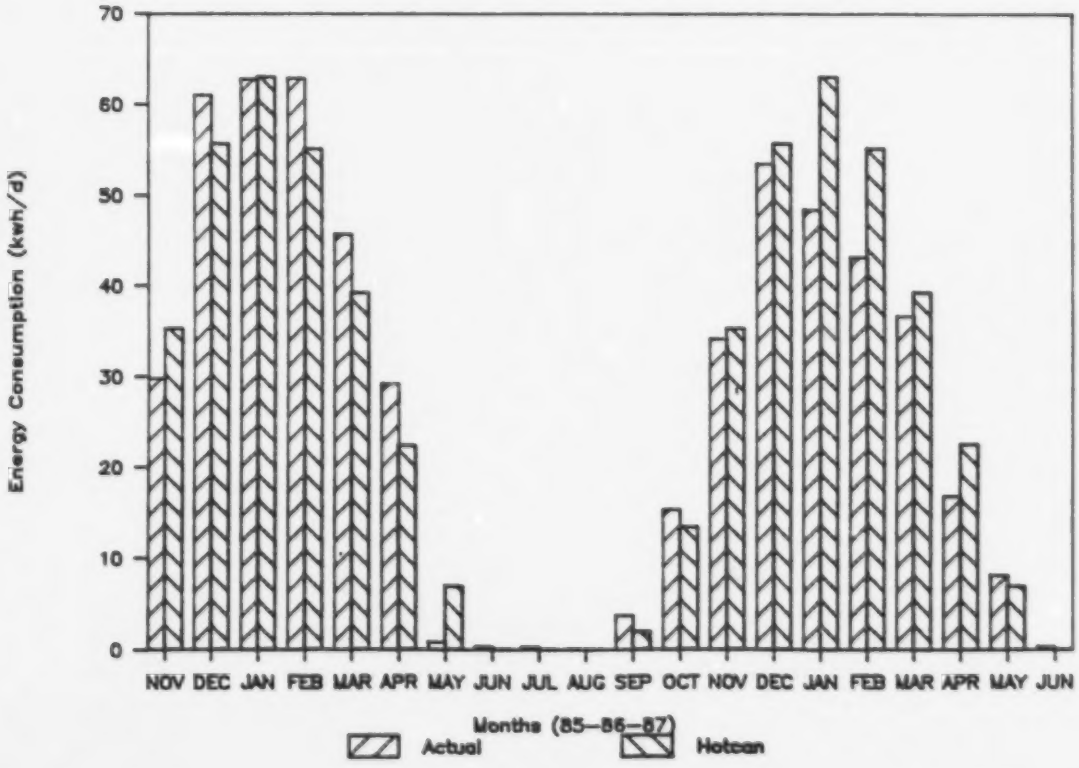
Appliances (Make & Type)
- Furnace: Olsen Minimax - natural gas
- DHW Heater: John Wood - electric
- Fireplace(s): No
- Air Conditioning: No

Floor Area: 202.1 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse:	31 - 45	
Number of occupants:	Adults: 2	Children:	2
Number home during the day:	Adults: 1	Children:	0

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 8,851 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 7,694 kWh

HOUSE E, SUDBURY, ONTARIO

Type of House: Back Split - Full basement

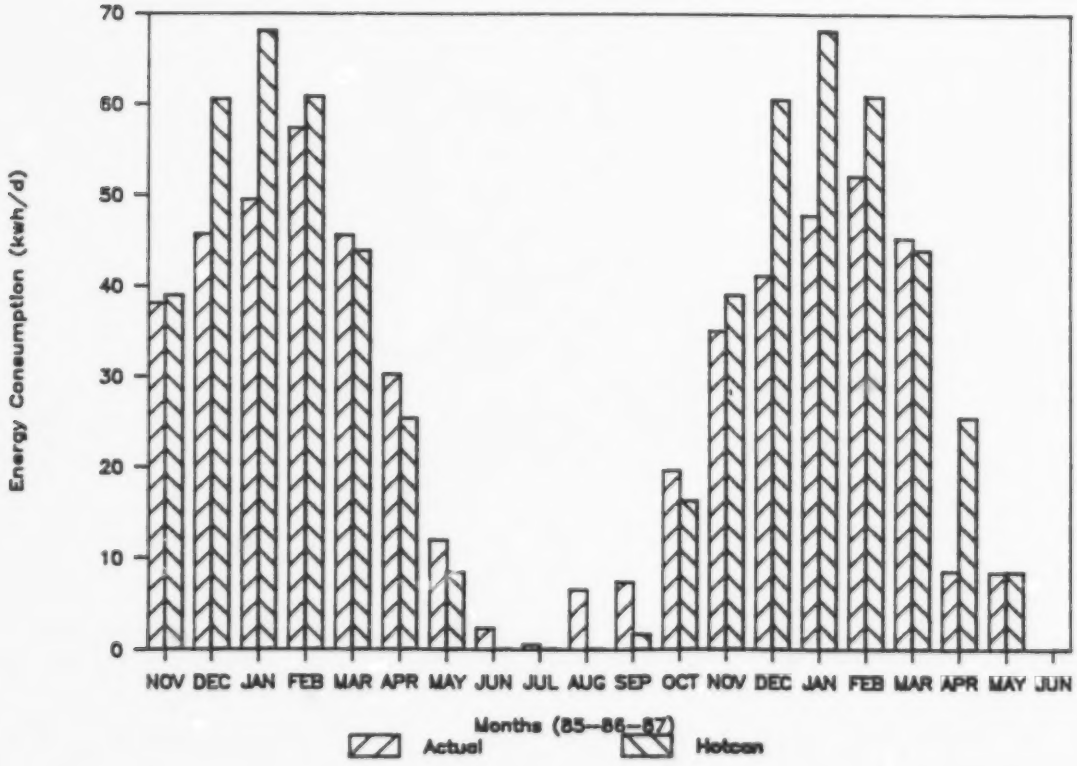
Appliances (Make & Type)
- Furnace: Olsen Duomatic Ultramax - natural gas
- DHW Heater: Rheems - electric
- Fireplace(s): One
- Air Conditioning: No

Floor Area: 222.9 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 3	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 9,782 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 8,460 kWh

HOUSE A, KINGSTON, ONTARIO

Type of House: 2 Storey - Full basement

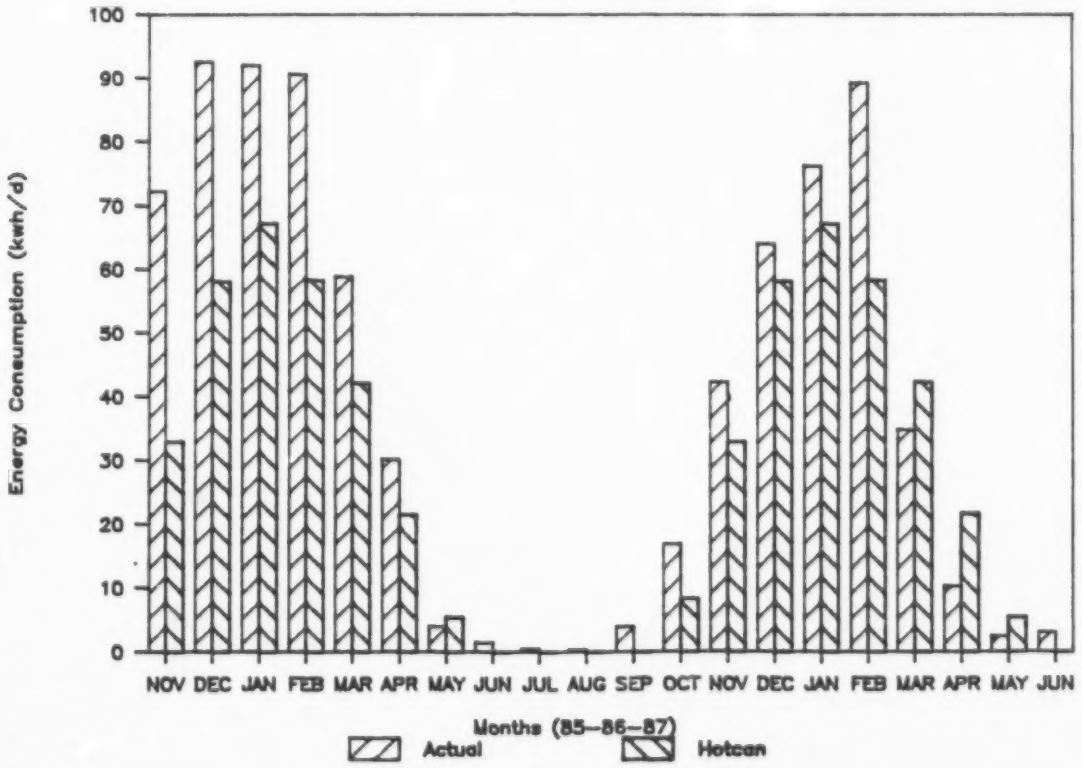
Appliances (Make & Type)
- Furnace: Summeraire - electric
- DHW Heater: John Wood - electric
- Fireplace(s): One
- Air Conditioning: No

Floor Area: 284.2 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 1	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 8,881 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 10,434 kWh

HOUSE B, KINGSTON, ONTARIO

Type of House: 2 Storey - Full Basement

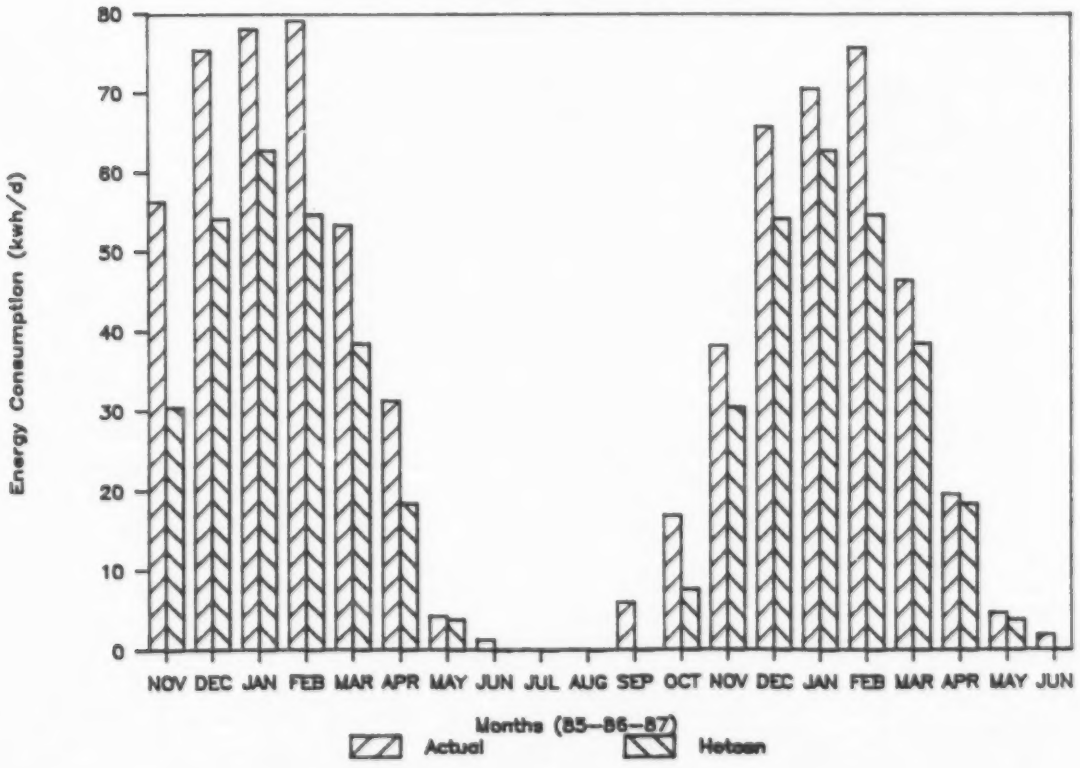
Appliances (Make & Type)
- Furnace: Lennox - electric
- DHW Heater: Ruud - electric
- Fireplace(s): One
- Air Conditioning: Yes

Floor Area: 258.8 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 2	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 8,170 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 10,467 kWh

HOUSE C, KINGSTON, ONTARIO

Type of House: 2 Storey - Full basement

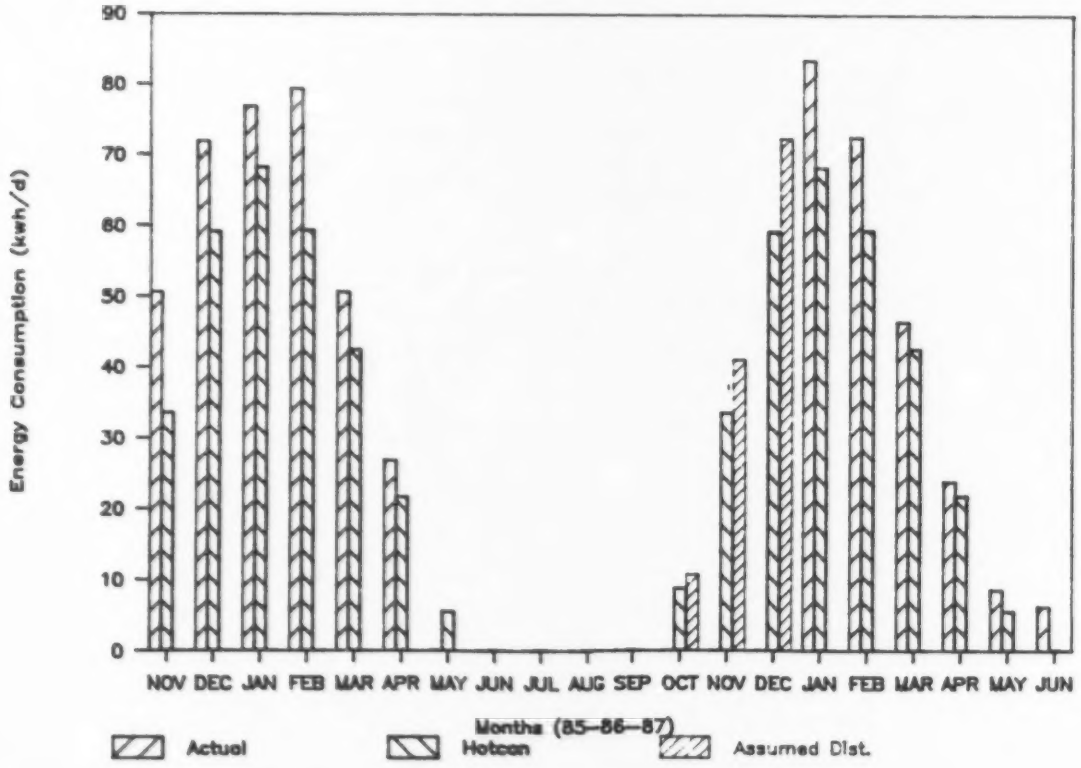
Appliances (Make & Type)
- Furnace: Lennox - electric
- DHW Heater: Rheem - electric
- Fireplace(s): one
- Air Conditioning: No

Floor Area: 269.6 m^2

Homeowner Profile (New Homeowner as of August 1986)

Age of owner: 46 - 60	Age of Spouse: 46 - 60		
Number of occupants:	Adults: 2	Children: 0	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 9,021 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 6,631 kWh

Note:
Actual values assumed for period from September to December 1986 -- Access to home was not possible

HOUSE D, KINGSTON, ONTARIO

Type of House: 2 Storey - Full basement

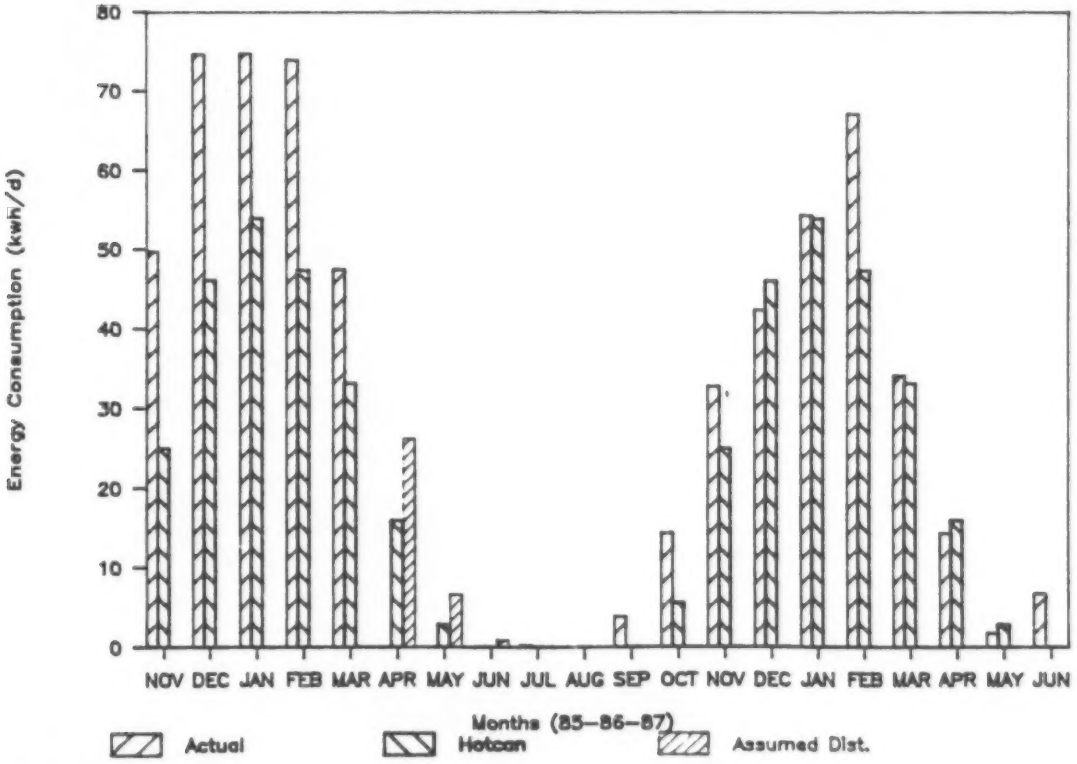
Appliances (Make & Type)
- Furnace: Luxaire (Borg Warner) - electric
- DHW Heater: Ruud - electric
- Fireplace(s): One
- Air Conditioning: No

Floor Area: 217.1 m^2

Homeowner Profile (New Homeowner as of June 1986)

Age of owner: 31 - 45	Age of Spouse: 18 - 30		
Number of occupants:	Adults: 2	Children: 0	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 6,935
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 8,120 kWh

Note:
Actual values assumed for period from April to June 1986 -- Access to home was not possible

HOUSE E, KINGSTON, ONTARIO

Type of House: 2 Storey - Full Basement

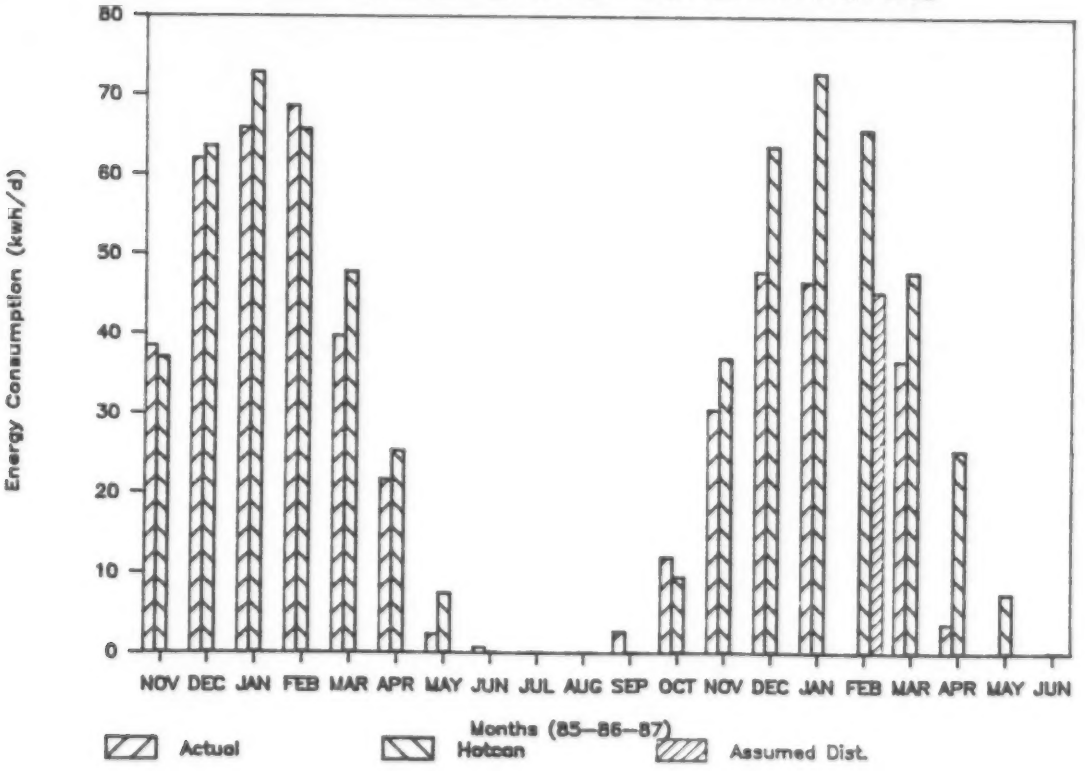
Appliances (Make & Type)
- Furnace: Lennox Pulse - natural gas
- DHW Heater: Ruud - electric
- Fireplace(s): One
- Air Conditioning: No

Floor Area: 284.2 m^2

Homeowner Profile

Age of owner: 46 - 60	Age of Spouse: 46 - 60		
Number of occupants:	Adults: 2	Children: 0	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 9,920 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 6,860 kWh

HOUSE A, FONTHILL, ONTARIO

Type of House: 2 Storey - Full basement

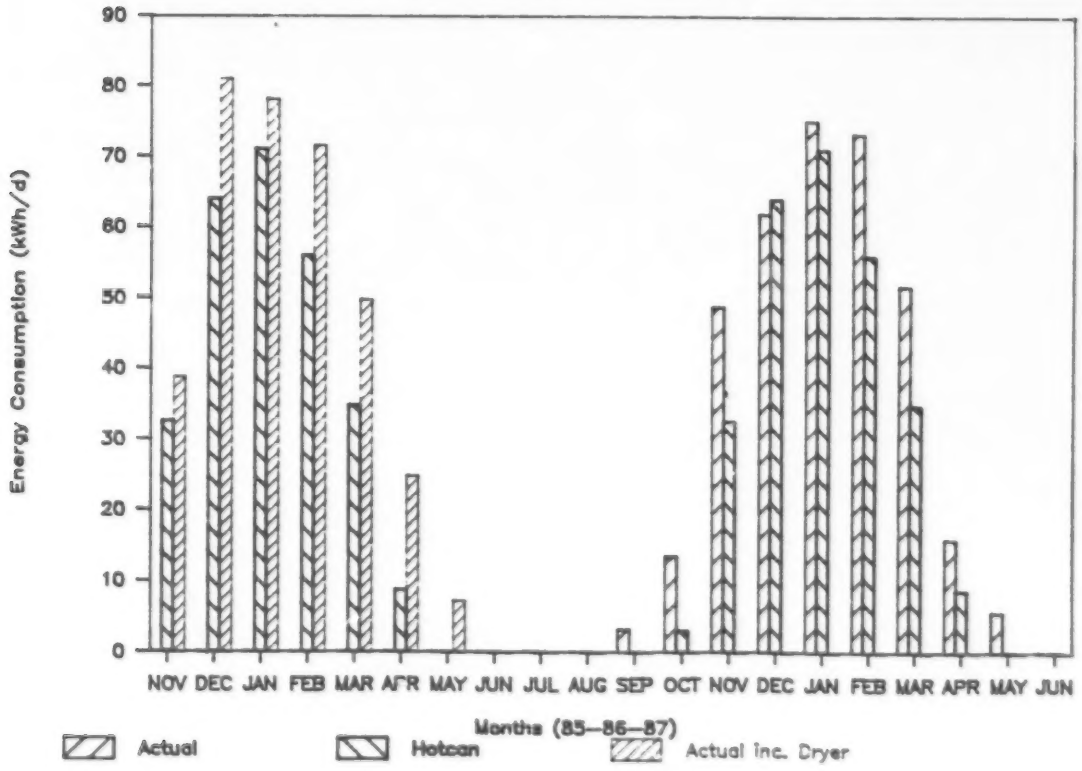
Appliances (Make & Type)
- Furnace: York - natural gas
- DHW Heater: Rheem - electric
- Fireplace(s): One
- Air Conditioning: No

Floor Area: 290.0 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 1	
Number home during the day:	Adults: 1	Children: 1	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 8,160 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 10,654 kWh

Note:
The Actual readings from November 1985 to May 1986 include the energy used for clothes drying.

HOUSE B, FONTHILL, ONTARIO

Type of House: 2 Storey, Full basement

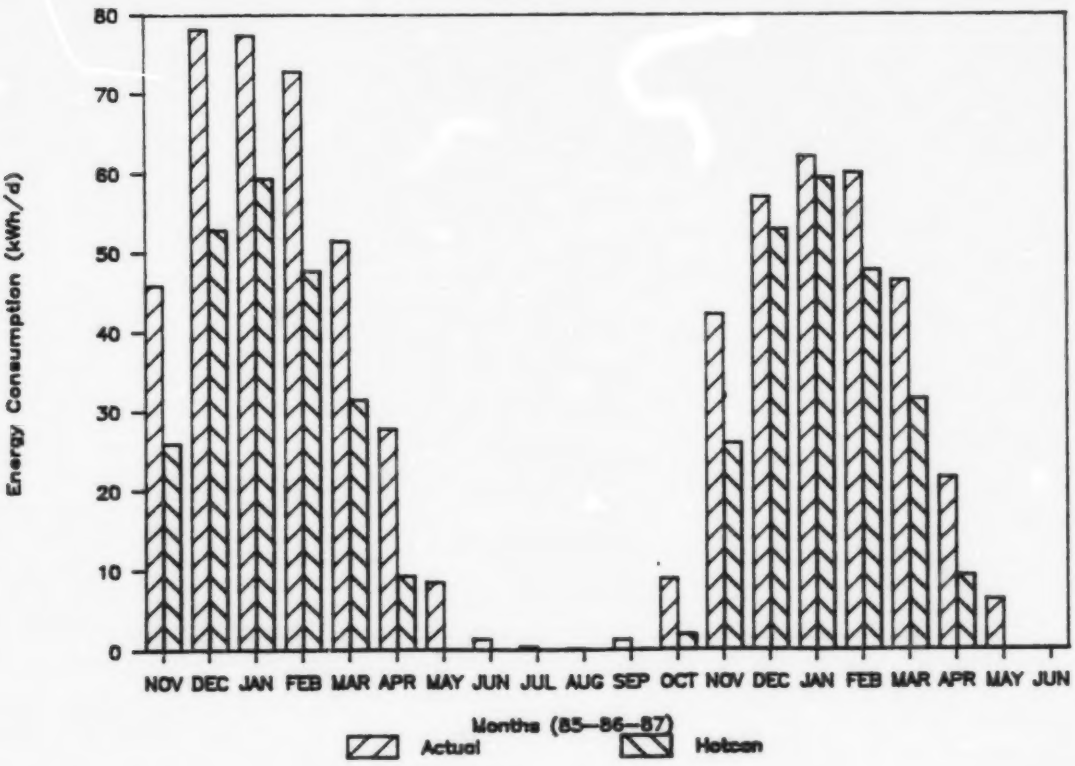
Appliances (Make & Type)
- Furnace: York - natural gas
- DHW Heater: Rheem - electric
- Fireplace(s): One
- Air Conditioning: No

Floor Area: 215.9 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children:	1-after Nov 85
Number home during the day:	Adults: 0	Children:	0

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 6,898 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 9,397 kWh

HOUSE C, FONTHILL, ONTARIO

Type of House: 2 Storey, Full basement

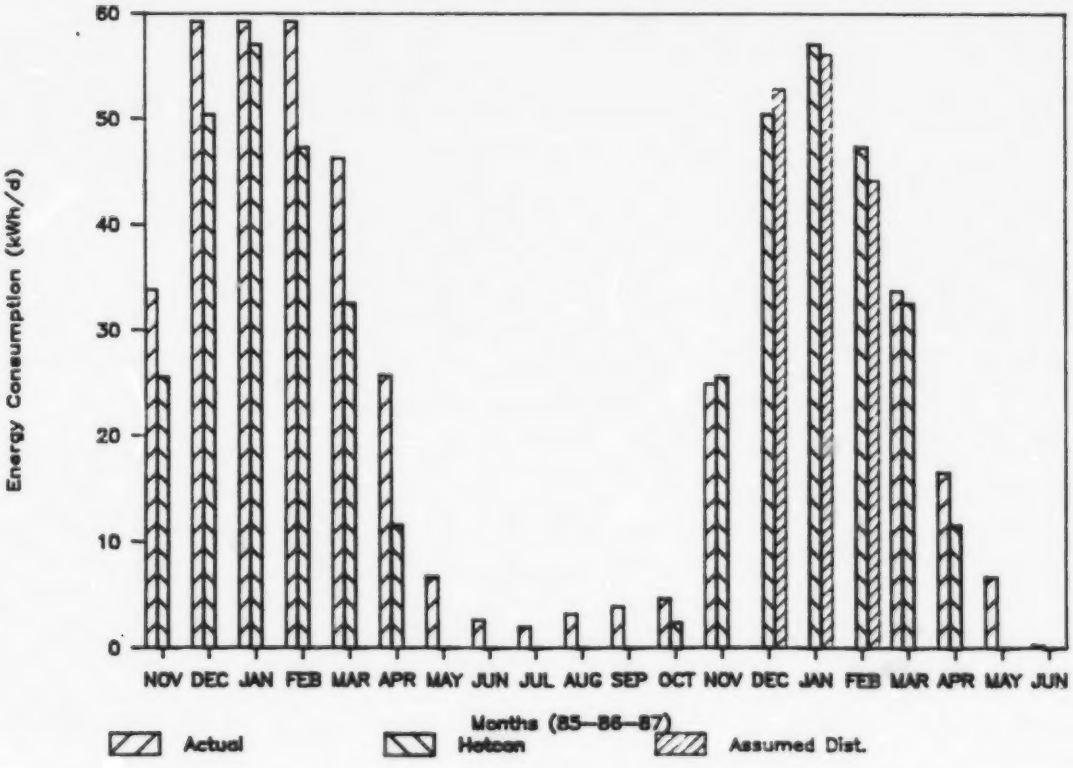
Appliances (Make & Type)
- Furnace: Clare - electric
- DHW Heater: G.S.W. - electric
- Fireplace(s): One
- Air Conditioning: No

Floor Area: 241.9 m^2

Homeowner Profile (New homeowner as of January 23, 1987)

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 3	
Number home during the day:	Adults: 1	Children: 1	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 6,855 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 7,500 kWh

HOUSE D, FONTHILL, ONTARIO

Type of House: 2 Storey, Full basement

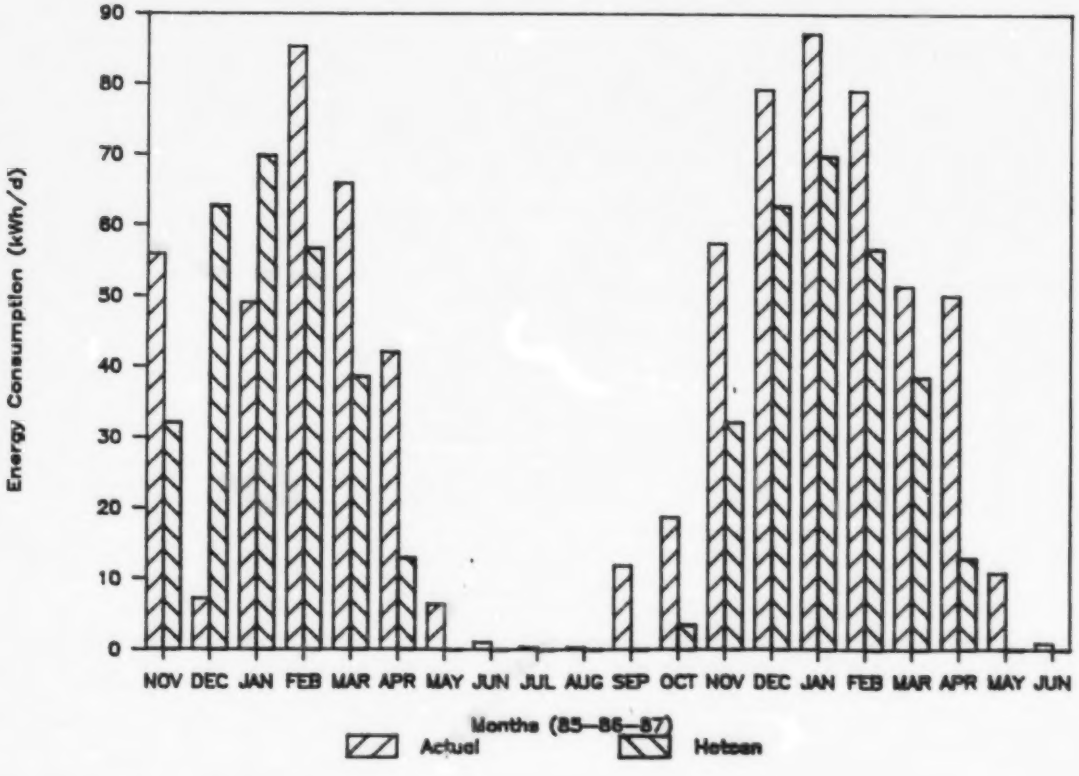
Appliances (Make & Type)
- Furnace: Clare - electric
- DHW Heater: Rheem - electric
- Fireplace(s): One
- Air Conditioning: Yes

Floor Area: 282.9 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 18 - 30		
Number of occupants:	Adults: 2	Children: 1	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 8,356 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 13,463 kWh

HOUSE E, FONTHILL, ONTARIO

Type of House: 2 Storey - Full basement

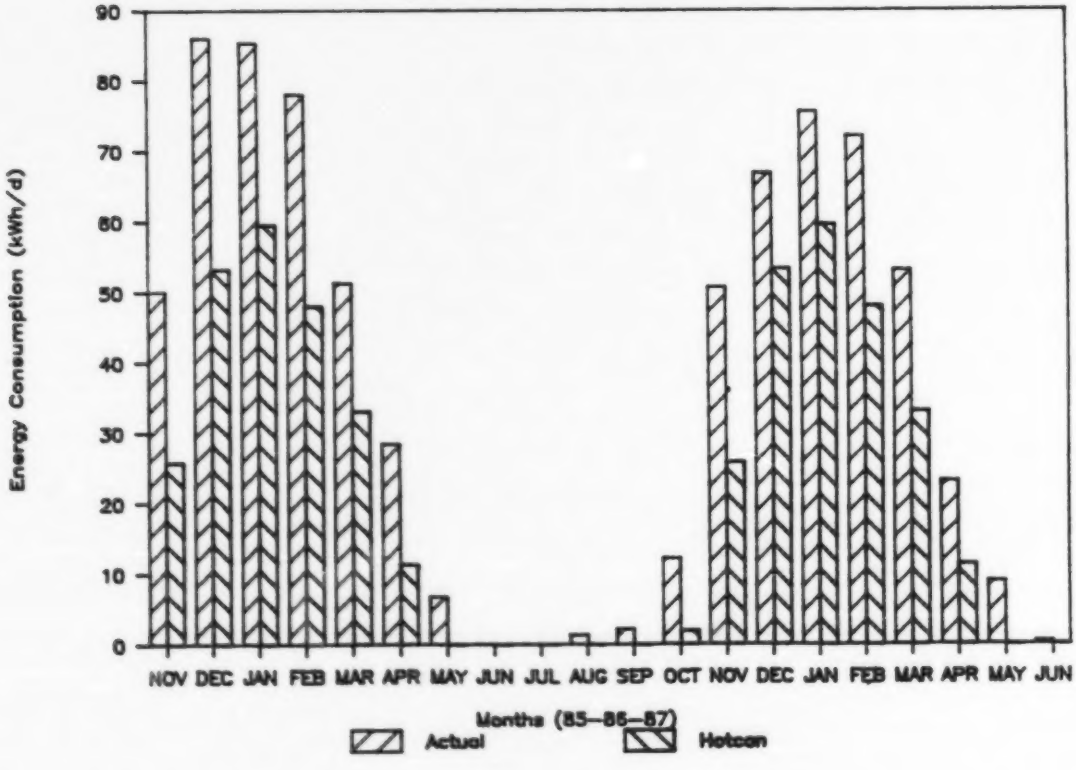
Appliances (Make & Type)
- Furnace: York - electric
- DHW Heater: Rheem - electric
- Fireplace(s): One
- Air Conditioning: No

Floor Area: 238.9 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 0	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 7,031 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 10,997 kWh

HOUSE A, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

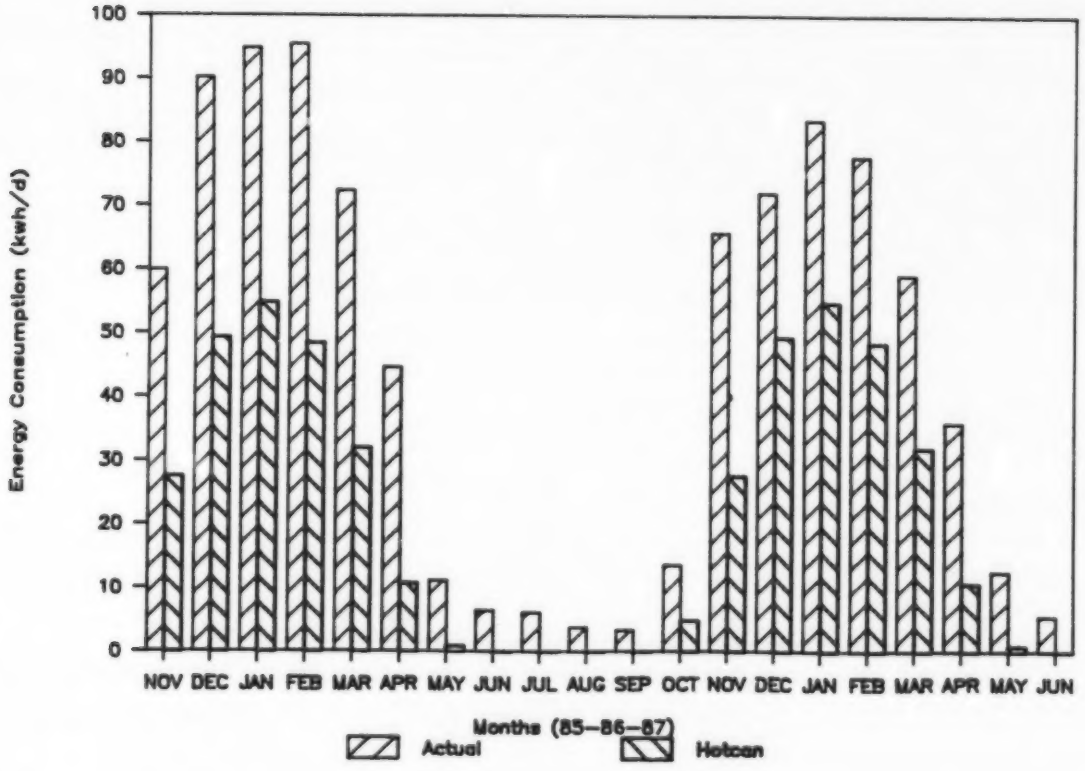
Appliances (Make & Type):
- Furnace: Clare Bros. - electric, single-speed fan
- DHW Heater: G.S.W. - electric
- Fireplace(s): Two
- Air Conditioning: No

Floor Area: 228.3 m^2

Homeowner Profile:

Age of owner: 31 - 45	Age of Spouse:	--	
Number of occupants:	Adults:	1	Children: 0
Number home during the day:	Adults:	0	Children: 0

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions:
- Space Heating: 6,909 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 13,316 kWh

HOUSE B, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

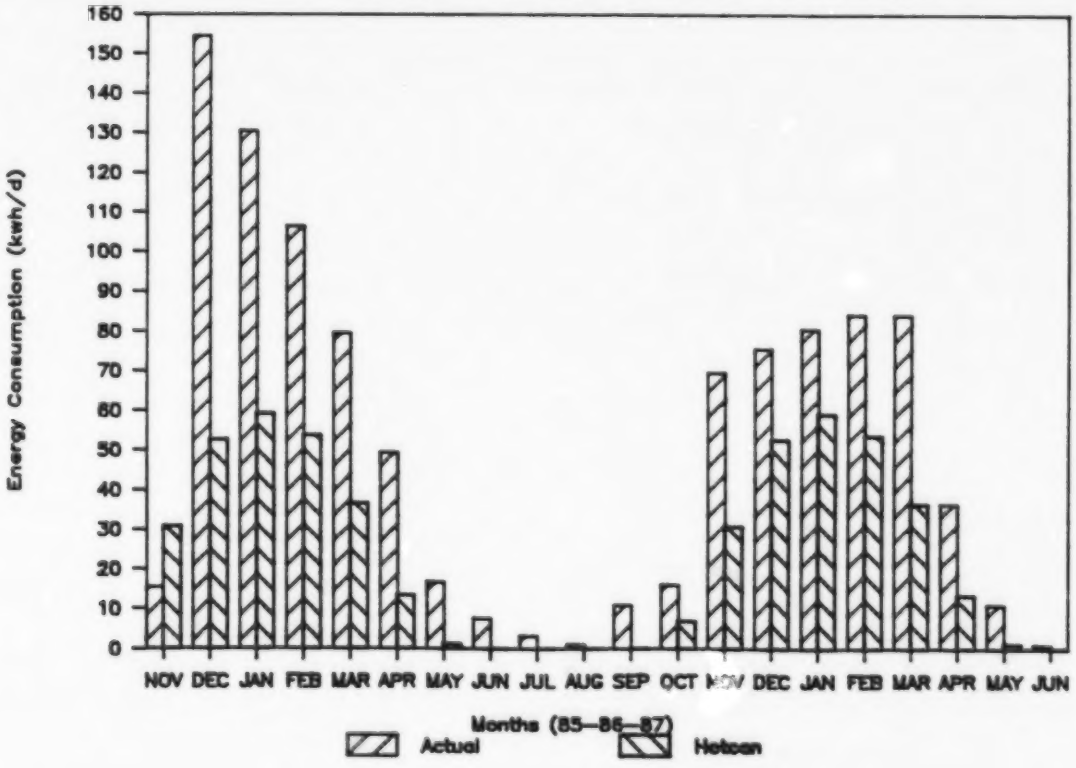
Appliances (Make & Type):
- Furnace: Clare Bros. - electric, single-speed fan
- DHW Heater: G.S.W. - electric
- Fireplace(s): Two
- Air Conditioning: No

Floor Area: 228.3 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 1	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions:
- Space Heating: 7,684 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 14,792 kWh

HOUSE C, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

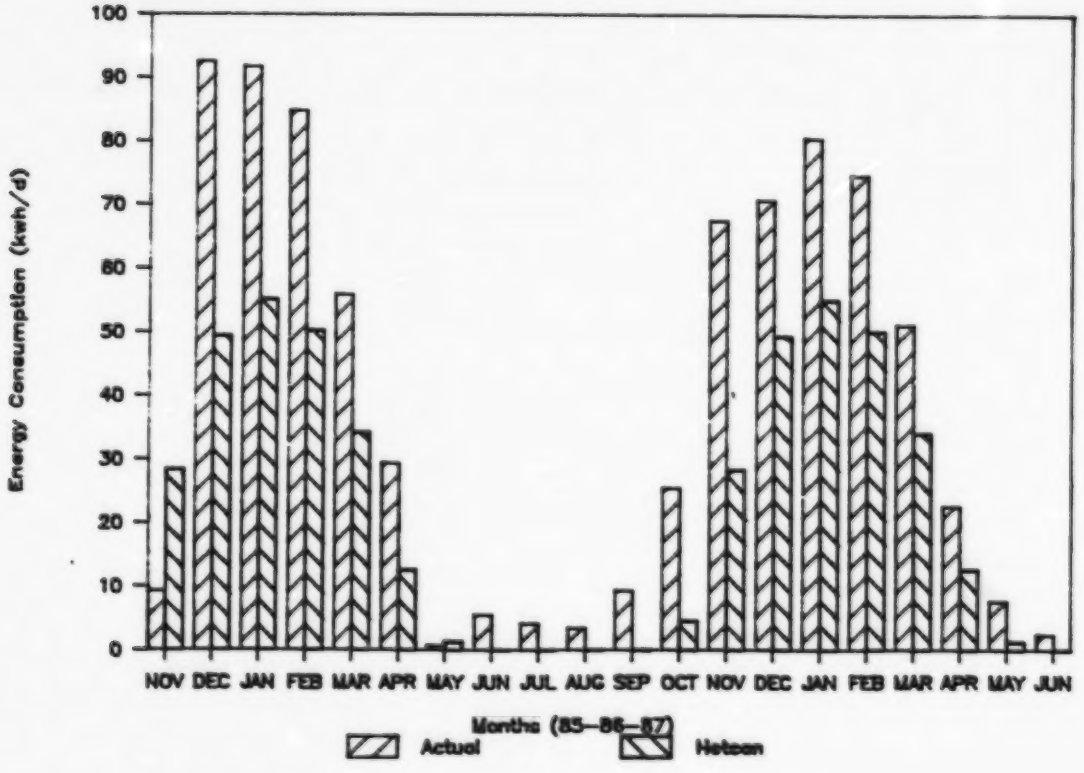
Appliances (Make & Type):
- Furnace: Clare Bros. - electric, single-speed fan
- DHW Heater: G.S.W. - electric
- Fireplace(s): Two
- Air Conditioning: Yes

Floor Area: 228.3 m^2

Homeowner Profile (New homeowner as of July 1986)

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 0	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions:
- Space Heating: 7,111 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 12,635 kWh

HOUSE D, ERIN MILLS, ONTARIO

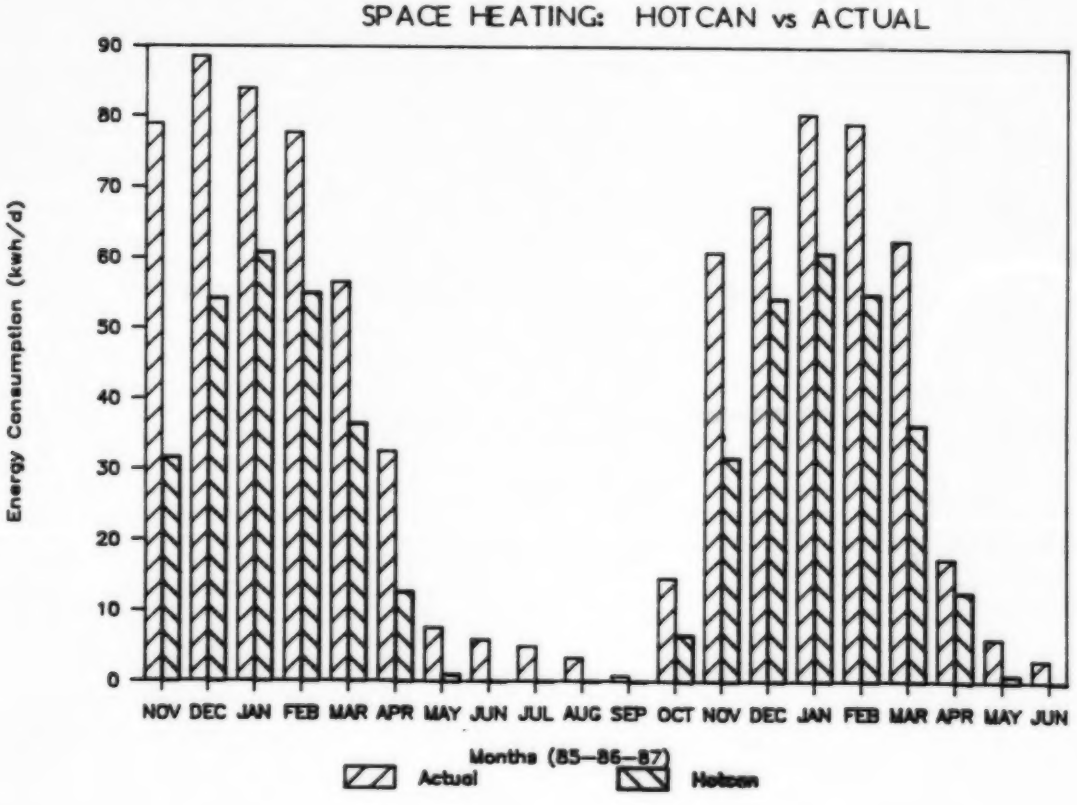
Type of House: Attached Row House - Unfinished full basement

Appliances (Make & Type):
- Furnace: Clare Bros. - electric, two-speed fan
- DHW Heater: G.S.W. - electric
- Fireplace(s): One
- Air Conditioning: Yes

Floor Area: 238.3 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse:		
Number of occupants:	Adults: 1	Children:	0
Number home during the day:	Adults: 0	Children:	0



Hotcan Predictions:
- Space Heating: 7,810 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 12,303 kWh

HOUSE E, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

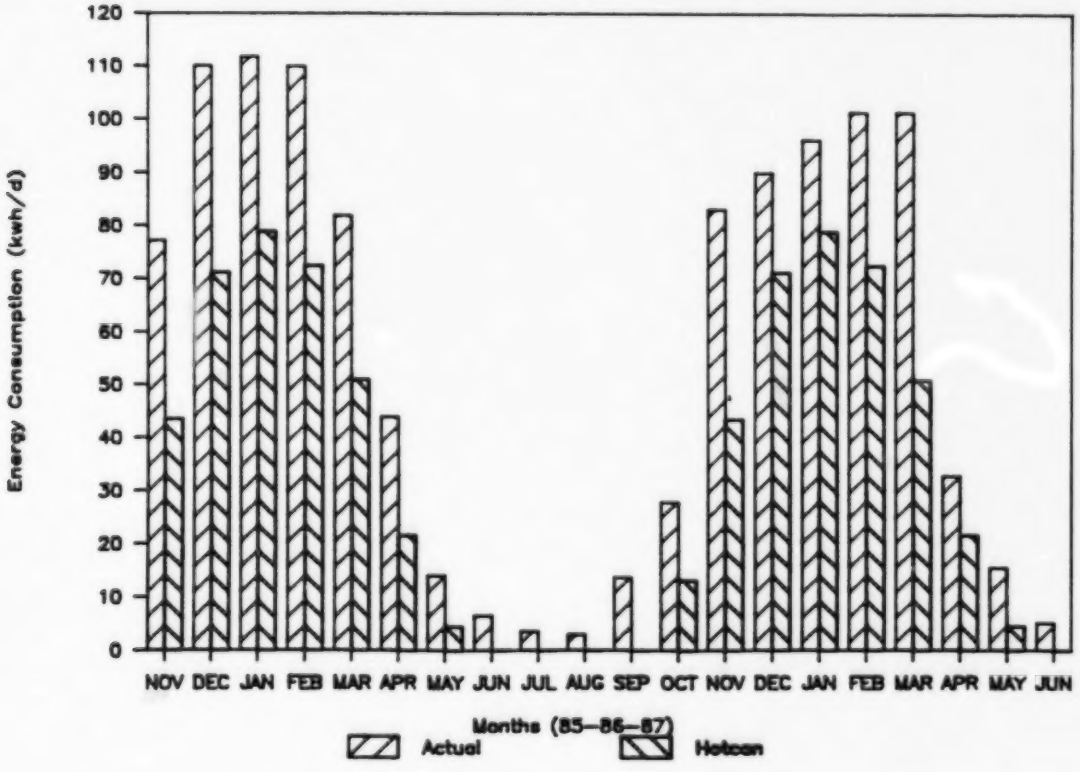
Appliances (Make & Type):
- Furnace: Clare Bros. - electric, single-speed fan
- DHW Heater: G.S.W. - electric
- Fireplace(s): One
- Air Conditioning: Yes

Floor Area: 249.6 m^2

Homeowner Profile

Age of owner:	46 - 60	Age of Spouse:	46 - 60
Number of occupants:		Adults: 5	Children: 0
Number home during the day:		Adults: 0	Children: 0

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions:
- Space Heating: 10,775 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 17,417 kWh

HOUSE F, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

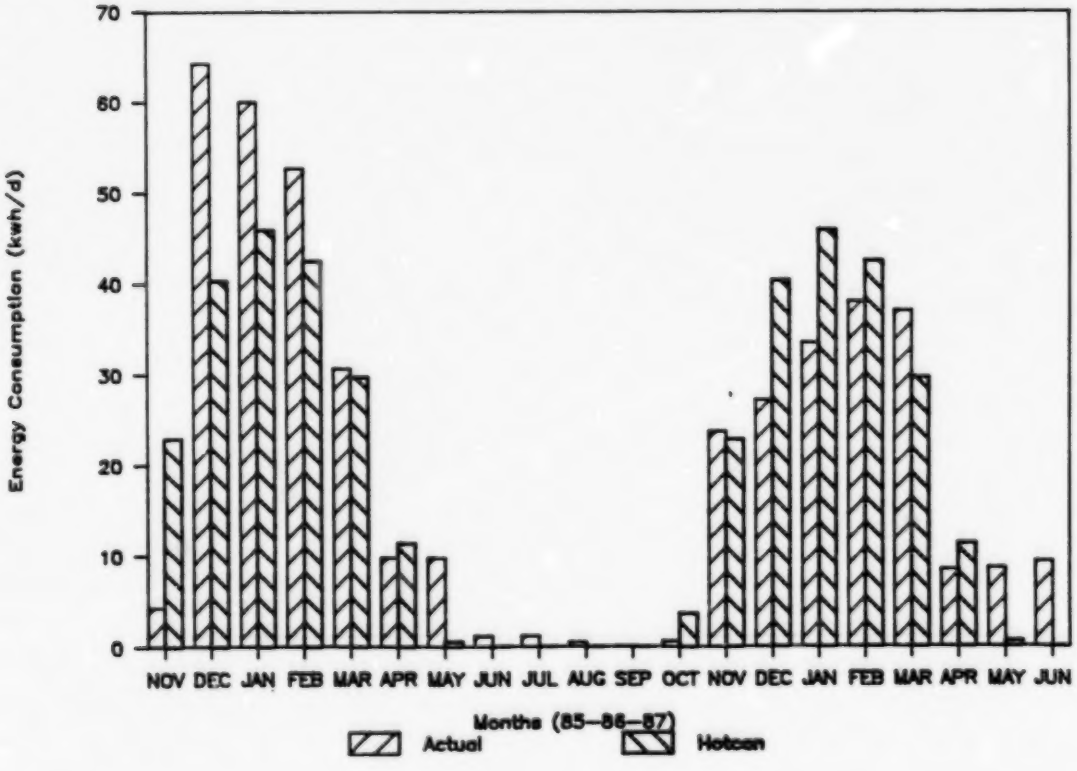
Appliances (Make & Type):
- Furnace: Clare Bros. - electric, single-speed fan
- DHW Heater: G.S.W. - electric
- Fireplace(s): One
- Air Conditioning: Yes

Floor Area: 215.4 m^2

Homeowner Profile

Age of owner:	46 - 60	Age of Spouse:	18 - 30
Number of occupants:		Adults: 2	Children: 0
Number home during the day:		Adults: 0	Children: 0

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions:
- Space Heating: 5,952 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 5,525 kWh

HOUSE G, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

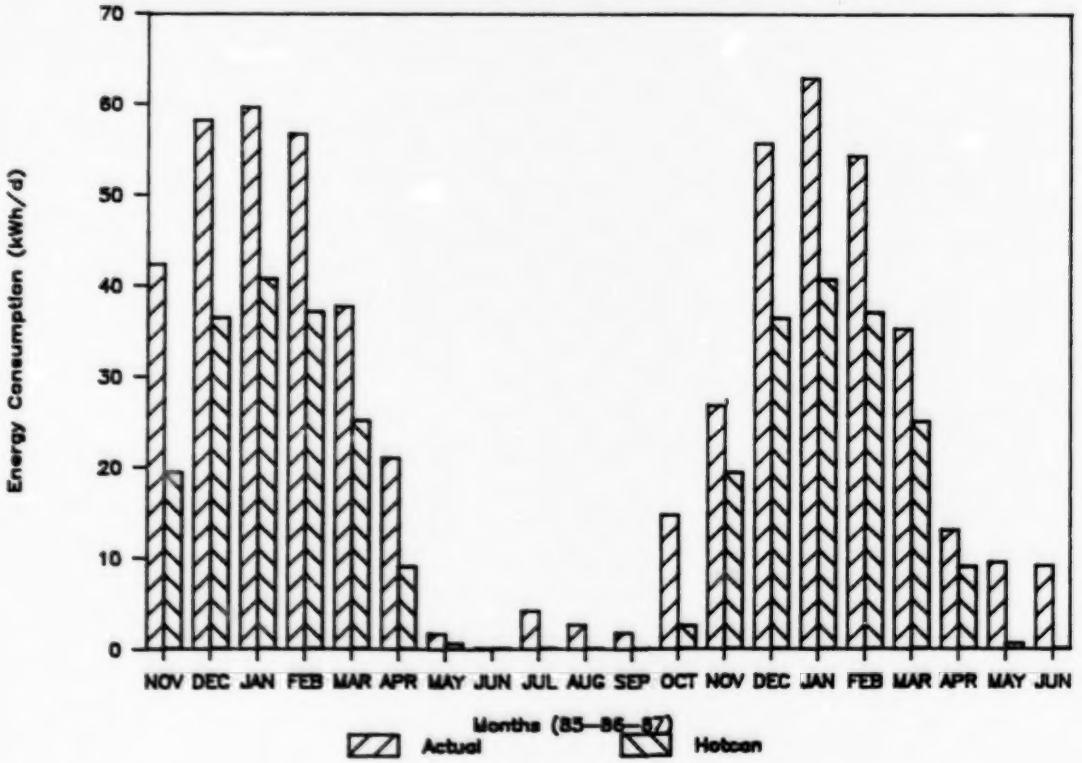
Appliances (Make & Type):
- Furnace: Clare Bros. - electric, two-speed fan
- DHW Heater: G.S.W. - electric
- Fireplace(s): One
- Air Conditioning: No

Floor Area: 215.4 m^2

Homeowner Profile (New homeowner as of November 1986)

Age of owner:	18 - 30	Age of Spouse:			
Number of occupants:		Adults:	1	Children:	0
Number home during the day:		Adults:	0	Children:	0

SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions:
- Space Heating: 5,154 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual Space Heating: 8,180 kWh

HOUSE H, PHASE II, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

Appliances (Make and Type):
- Furnace: Lennox - electric
- DHW Heater: G.S.W. - electric
- Fireplace(s): Two
- Air Conditioning: Yes

Floor Area: 249.6 m^2

Homeowner Profile

Age of owner: 46 - 60		Age of Spouse: 46 - 60	
Number of Occupants:		Adults: 3	Children: 0
Number home during the day:		Adults: 1	Children: 0

Note: Space heating data was not available for the 1986/87 heating season.

HOUSE I, PHASE II, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

Appliances (Make and Type):
- Furnace: Lennox - electric
- DHW Heater: G.S.W. - electric
- Fireplace(s): One
- Air Conditioning: Yes

Floor Area: 215.4 m^2

Homeowner Profile:

Age of owner: 18 - 30	Age of Spouse:	-	
Number of Occupants:	Adults: 1	Children:	1
Number home during the day:	Adults: 0	Children:	0

Note: Space heating data was not available for the 1986/87 heating season.

HOUSE J, PHASE II, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

Applicances (Make and Type)
- Furnace: Lennox - electric
- DHW Heater: G.S.W. - electric
- Fireplace(s): One
- Air Conditioning: Yes

Floor Area: 215.4 m^2

Homeowner Profile

Age of owner: 31 - 45		Age of Spouse: 18 - 30	
Number of occupants:		Adults: 3	Children: 0
Number home during the day:		Adults: 0	Children: 0

Note: Space heating data was not available for the 1986/87 heating season.

HOUSE K, PHASE II, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

Appliances (Make and Type):
- Furnace: Lennox - electric
- DHW Heater: G.S.W. electric
- Fireplace(s): No
- Air Conditioning: Yes

Floor Area: 228.3 m^2

Homeowner Profile

Age of owner:	18 - 30	Age of Relative:	45 - 60
Number of occupants:		Adults: 2	Children: 0
Number home during the day:		Adults: 1	Children: 0

Note: Space heating data was not available for the 1986/87 heating season.

HOUSE L, PHASE II, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

Appliances (Make and Type):
- Furnace: Lennox - electric
- DHW Heater: G.S.W. - electric
- Fireplace(s): One
- Air Conditioning: Yes

Floor Area: 228.3 m^2

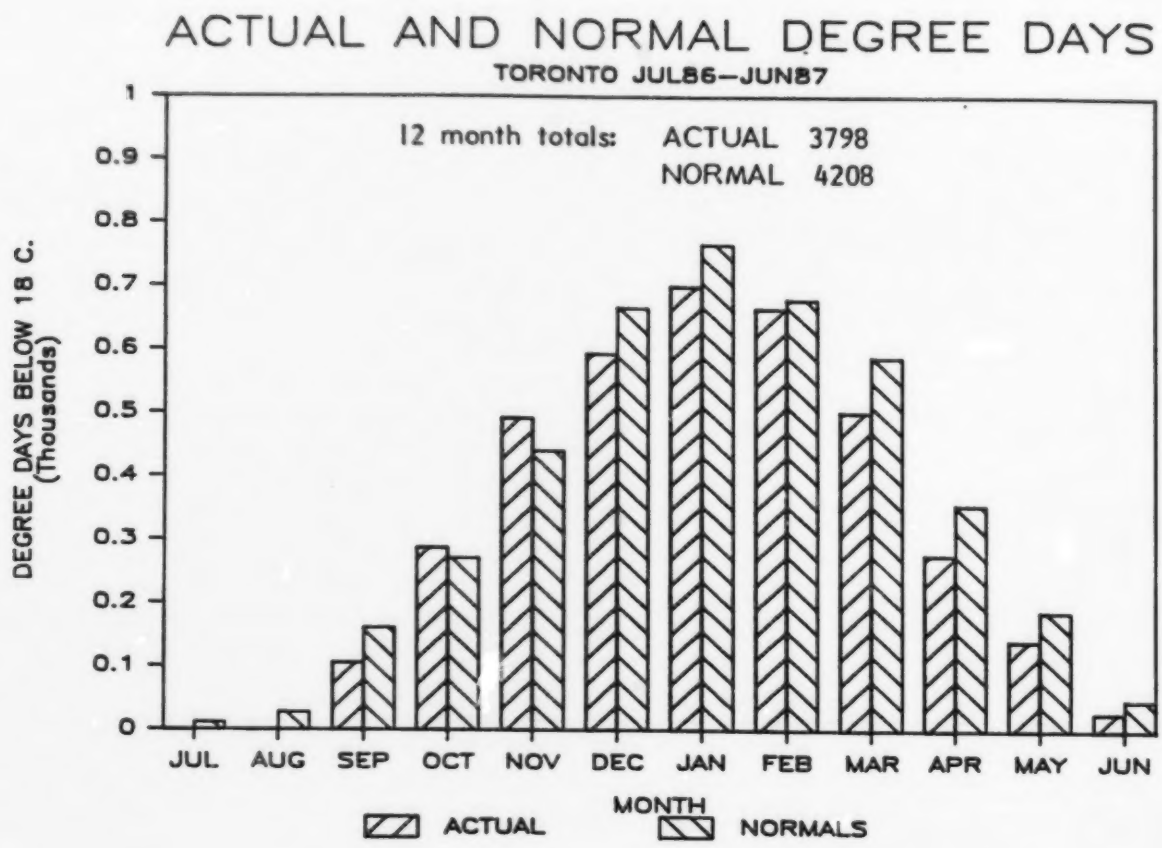
Homeowner Profile

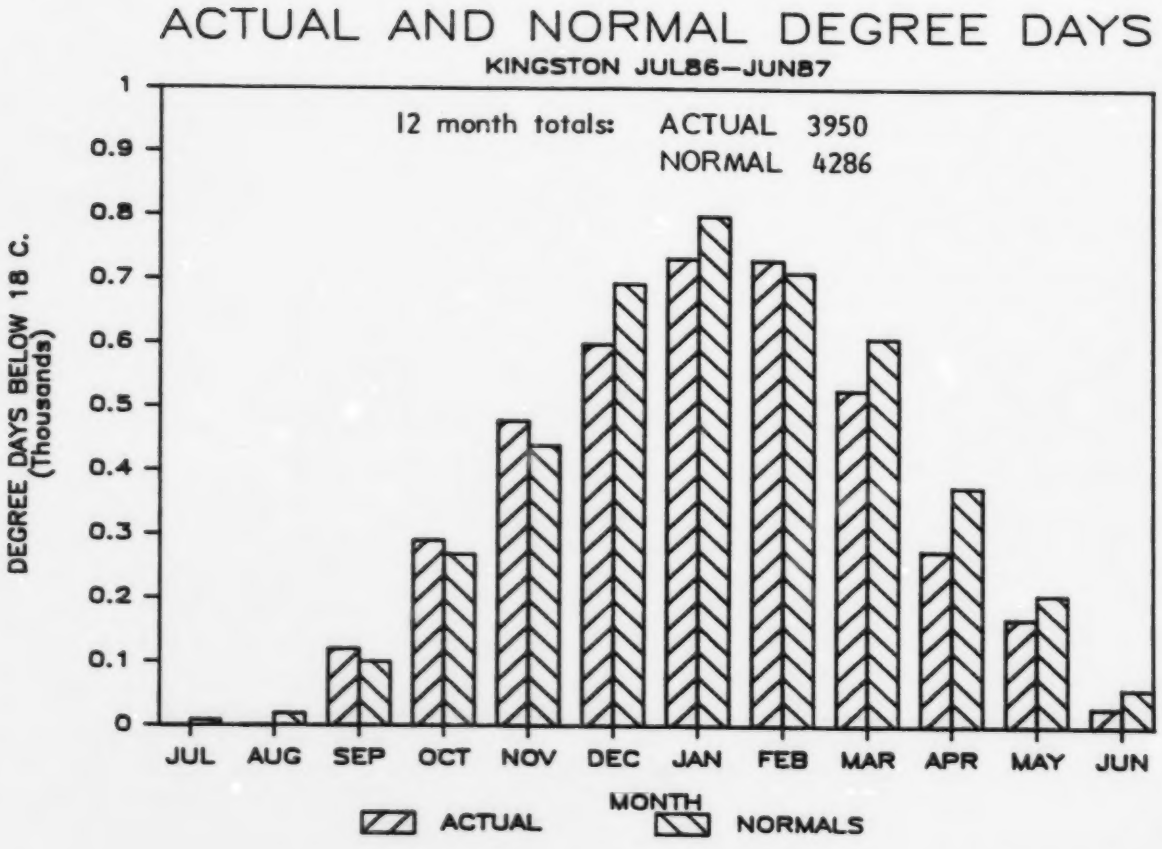
Age of owner: -	Age of Spouse: -		
Number of occupants:	Adults: 1	Children:	0
Number home during the day:	Adults: 0	Children:	0

Note: Space heating data was not available for the 1986/87 heating season.

APPENDIX B

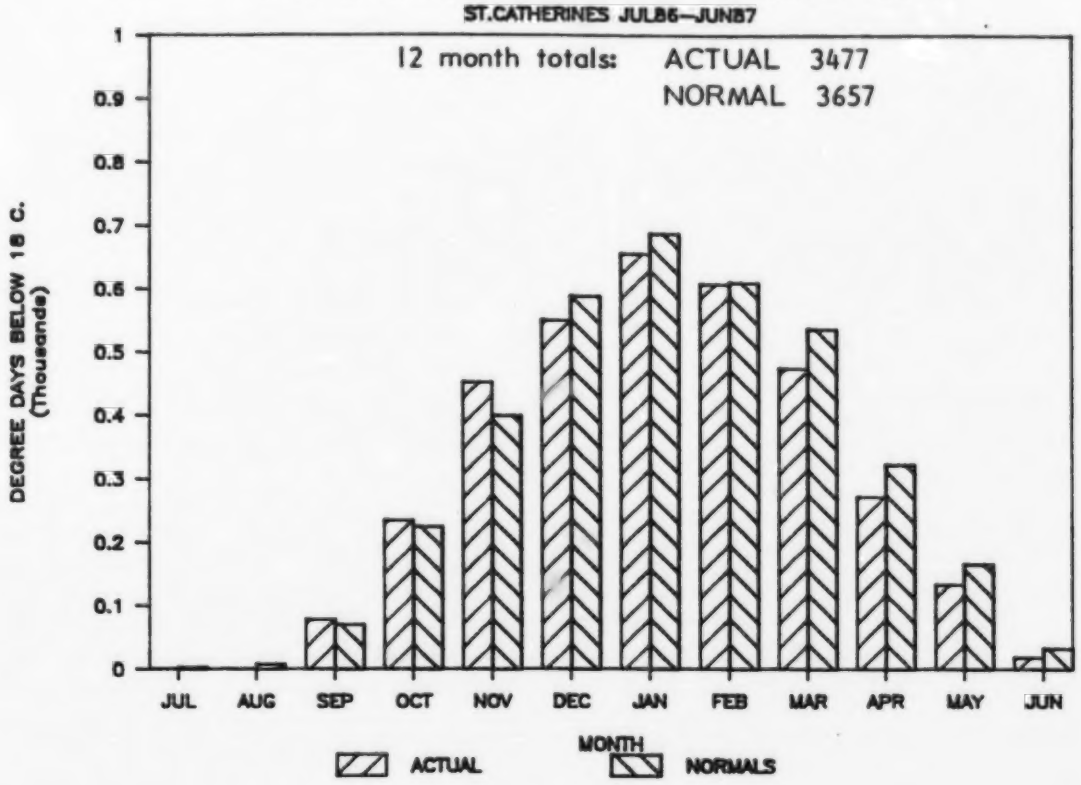
WEATHER DATA


ACTUAL AND NORMAL DEGREE DAYS
TORONTO JUL86–JUN87
12 month totals: ACTUAL 3798
NORMAL 4208
DEGREE DAYS BELOW 18 C.
(Thousands)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN
MONTH
ACTUAL
NORMALS


ACTUAL AND NORMAL DEGREE DAYS
KINGSTON JUL86–JUN87
12 month totals: ACTUAL 3950
NORMAL 4286
DEGREE DAYS BELOW 18 C.
(Thousands)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN
MONTH
ACTUAL
NORMALS

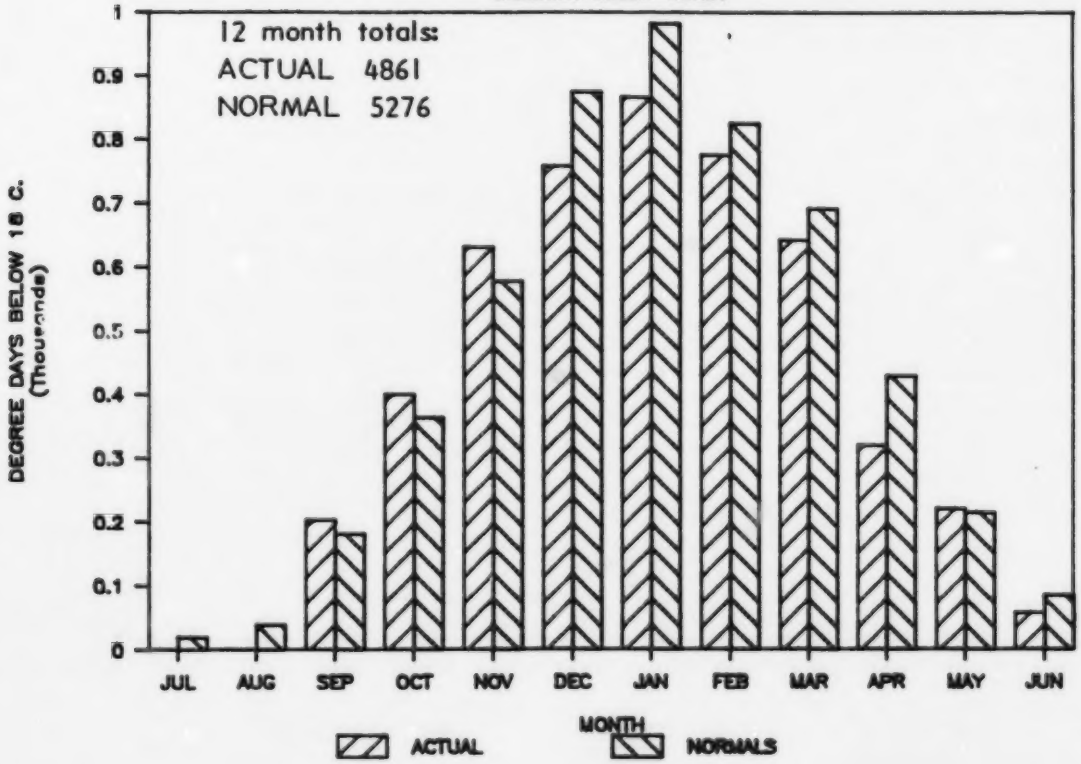
ACTUAL AND NORMAL DEGREE DAYS

ST.CATHERINES JUL86—JUN87



ACTUAL AND NORMAL DEGREE DAYS

SUDBURY JUL86—JUN87



APPENDIX C

STATISTICAL SUMMARY OF ENERGY DATA

TABLE C-I ANNUAL SPACE HEATING ENERGY CONSUMPTION
(R-2000 Target, Actual 1985/86, Actual 1986/87, HOTCAN and HOT-2000)

	R-2000 Target ($kWh/m^2/y$)	Actual 85/86 ($kWh/m^2/y$)	Actual 86/87 ($kWh/m^2/y$)	HOTCAN Predicted ($kWh/m^2/y$)	HOT-2000 Predicted ($kWh/m^2/y$)
SUDBURY					
House A	45.0	56.3	51.9	44.3	45.0
House B	41.0	33.7	31.0	39.5	46.3
House C	44.8	56.1	33.8	42.4	49.5
House D	43.5	45.2	38.1	43.8	52.0
House E	40.1	40.1	37.9	43.9	42.1
KINGSTON					
House A	34.9	47.4	36.7	31.3	29.6
House B	34.9	44.6	40.4	31.5	29.8
House C	34.8	39.0	39.5	33.4	32.1
House D	34.9	50.3	37.9	32.0	29.9
House E	34.9	30.8	24.2	34.9	32.0
FONTHILL					
House A	32.1	38.0	36.7	28.1	40.6
House B	32.1	58.4	43.5	31.9	46.8
House C	32.0	34.7	31.3	28.3	30.9
House D	32.1	45.5	47.6	29.5	48.3
House E	32.1	49.1	46.2	29.4	34.2
ERIN MILLS Phase I					
House A	33.1	62.7	58.4	30.3	-
House B	33.4	76.4	64.9	33.7	-
House C	33.4	57.1	55.4	31.2	-
House D	31.7	55.5	51.7	32.8	-
House E	33.2	68.9	69.7	43.1	-
House F	32.2	37.0	25.7	27.7	-
House G	32.2	43.7	38.7	24.0	-
ERIN MILLS Phase II					
House H	33.2	-	-	-	-
House I	32.2	-	-	-	-
House J	32.2	-	-	-	-
House K	33.4	-	-	-	-
House L	33.4	-	-	-	-
Average	34.9	48.7	42.0	34.0	39.3

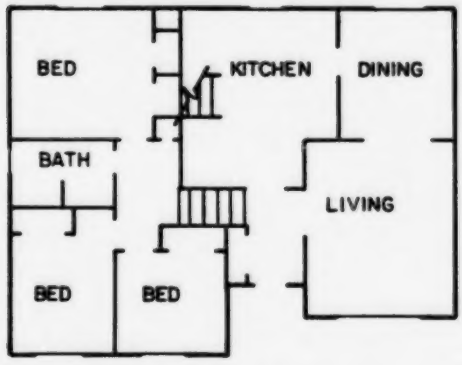
TABLE C-2 AVERAGE DAILY CONSUMPTION OF SPACE HEATING ENERGY
(R-2000 Target and Actual 1986/87)

	R-2000 Target (kWh/d)	Actual 86/87 (kWh/d)
SUDBURY		
House A	24.6	28.3
House B	22.3	16.9
House C	24.4	18.5
House D	24.1	21.1
House E	24.5	23.2
KINGSTON		
House A	27.2	28.6
House B	24.7	28.7
House C	25.8	29.2
House D	20.8	22.6
House E	27.2	18.8
FONTHILL		
House A	25.5	29.2
House B	19.0	25.7
House C	21.2	20.8
House D	24.9	36.9
House E	21.0	30.3
ERIN MILLS Phase I		
House A	20.7	36.5
House B	20.9	40.5
House C	20.9	34.6
House D	20.7	33.7
House E	22.7	47.7
House F	19.0	15.1
House G	19.0	22.8

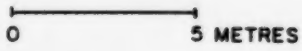
TABLE C-3 ANNUAL SPACE HEATING ENERGY CONSUMPTION
(Actual 1986/87, HOTCAN, HOT-2000 and R-2000 Target)

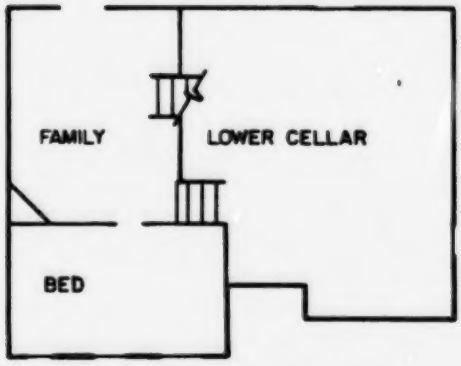
	85/86 ACTUAL (kWh/y)	86/87 ACTUAL (kWh/y)	HOTCAN (kWh/y)	HOT-2000 (kWh/y)	R-2000 TARGET (kWh/y)
SUDBURY					
House A	11200	10322	8809	8951	8964
House B	6698	6161	7866	9218	8150
House C	11163	6735	8432	9846	8910
House D	9137	7694	8851	10508	8783
House E	8936	8460	9782	9387	8946
KINGSTON					
House A	13472	10434	8881	8393	9918
House B	11562	10467	8170	7721	9031
House C	10521	10672	9021	8654	9409
House D	10907	8234	6935	6495	7577
House E	8748	6860	9920	9085	9918
FONTHILL					
House A	11024	10654	8160	11770	9306
House B	12617	9397	6898	10104	6926
House C	8387	7585	6855	7477	7755
House D	12868	13463	8356	13658	9078
House E	11739	11053	7031	8180	7661
ERIN MILLS Phase I					
House A	14291	13316	6909	-	7548
House B	17430	14792	7684	-	7620
House C	13027	12635	7111	-	7620
House D	13210	12303	7810	-	7548
House E	17217	17417	10775	-	8299
House F	7950	5525	5952	-	6926
House G	9401	8322	5154	-	6926
ERIN MILLS Phase II					
House H	-	-	-	-	8299
House I	-	-	-	-	6926
House J	-	-	-	-	6926
House K	-	-	-	-	7620
House L	-	-	-	-	7620

HOUSE A, SUDBURY



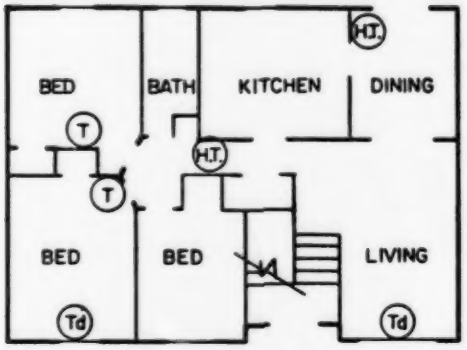
UPPER FLOOR AND MIDDLE FLOOR





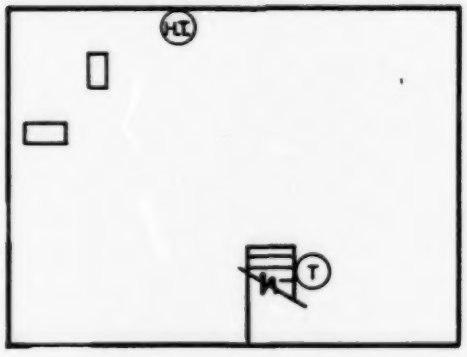
LOWER FLOOR AND BASEMENT

HOUSE B, SUDBURY



GROUND FLOOR

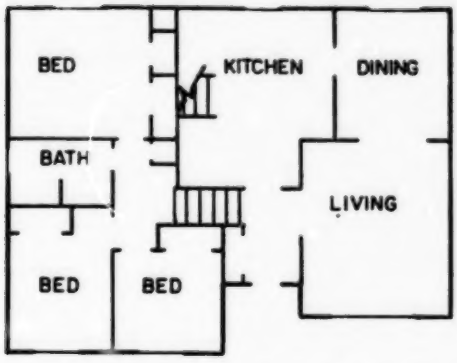
0 5 METRES



BASEMENT

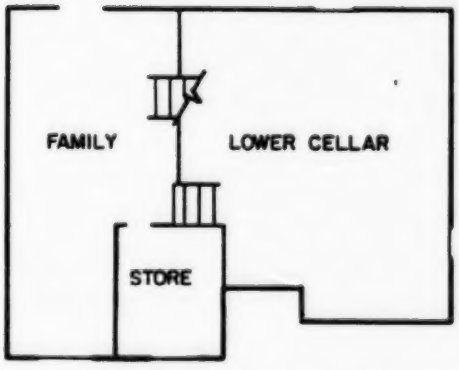
T - Wall Mounted Temperature Sensor
Td - Duct Mounted Temperature Sensor
HT - Wall Mounted Humidity/Temperature Sensor

HOUSE C, SUDBURY



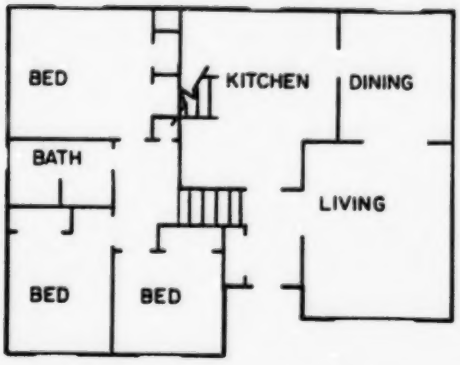
UPPER FLOOR AND MIDDLE FLOOR

0 5 METRES



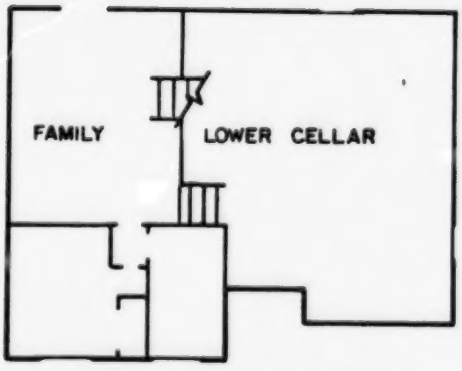
LOWER FLOOR AND BASEMENT

HOUSE D, SUDBURY



UPPER FLOOR AND MIDDLE FLOOR

0 5 METRES

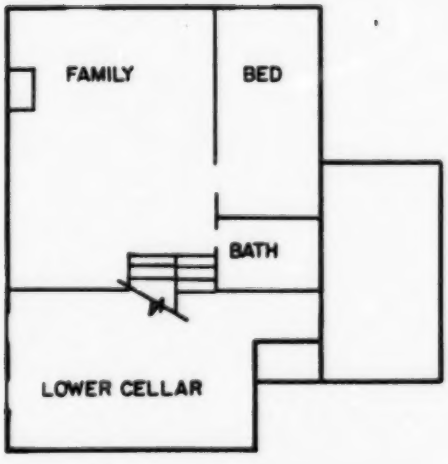


LOWER FLOOR AND BASEMENT

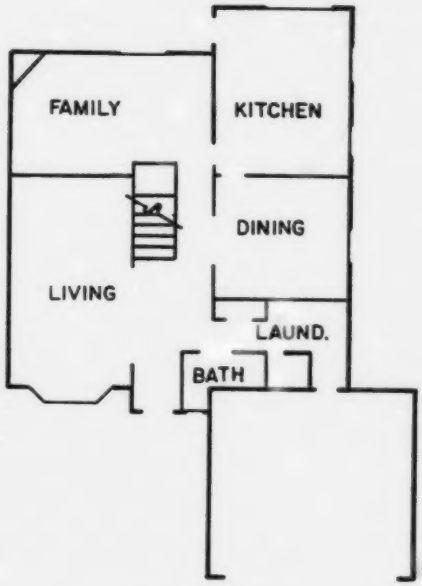
HOUSE E, SUDBURY

UPPER FLOOR AND MIDDLE FLOOR

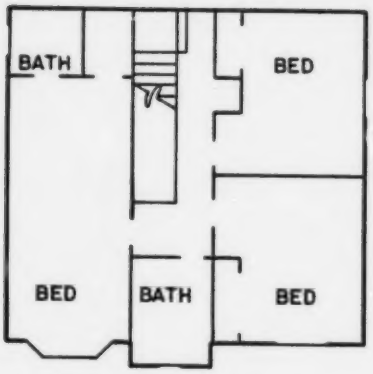
0 5 METRES



LOWER FLOOR AND BASEMENT

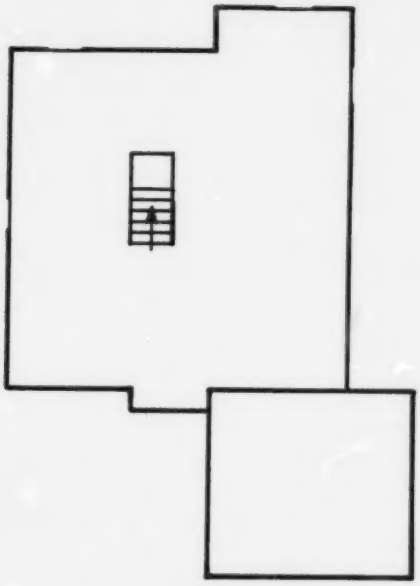


GROUND FLOOR



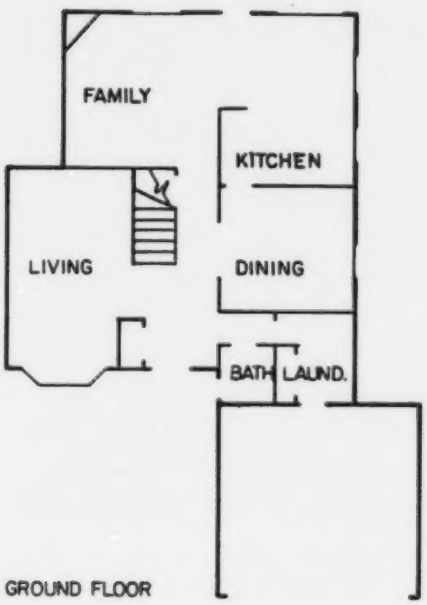
SECOND FLOOR

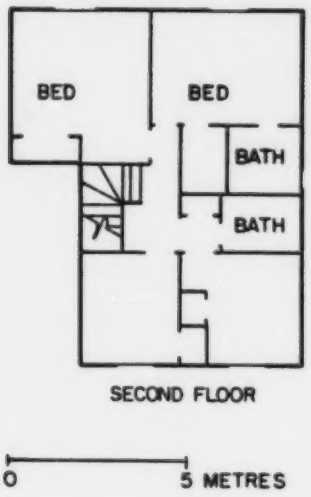
0 5 METRES

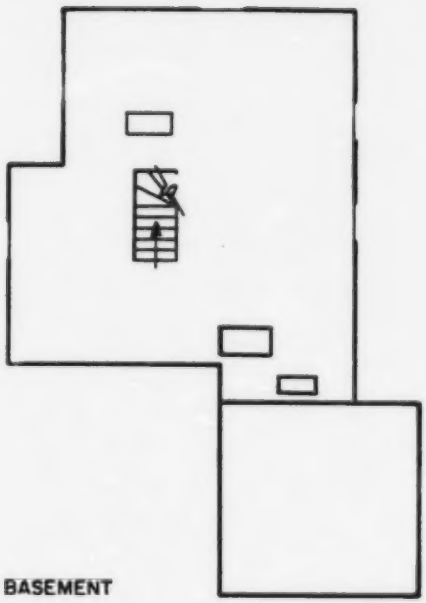


BASEMENT

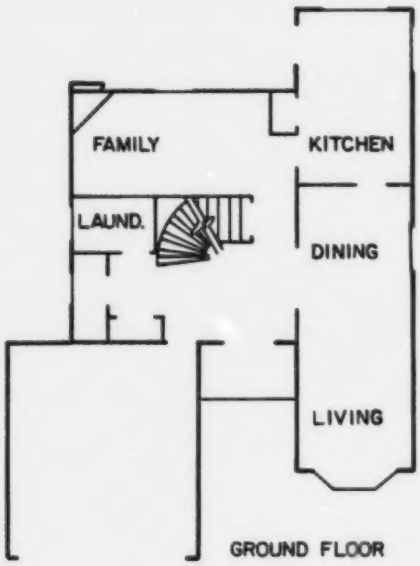
HOUSE A, KINGSTON

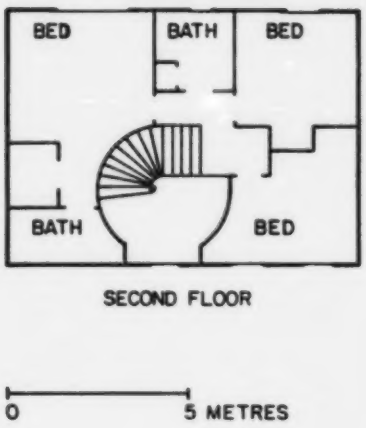


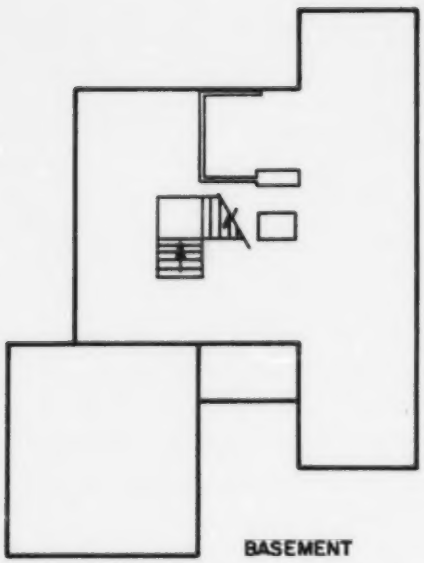




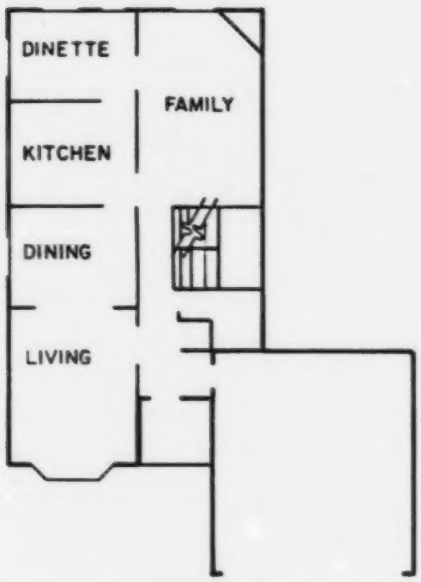
HOUSE B, KINGSTON



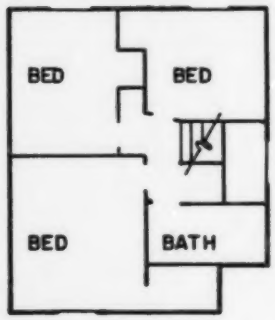




HOUSE C, KINGSTON

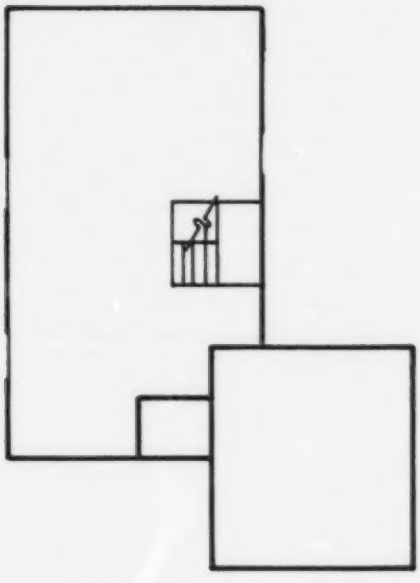


GROUND FLOOR



SECOND FLOOR

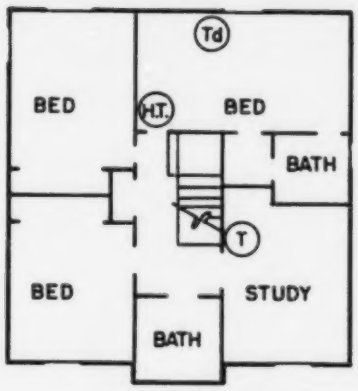
0 5 METRES



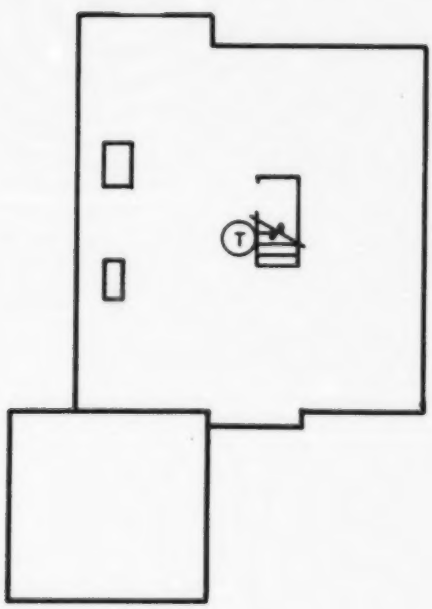
BASEMENT

HOUSE D, KINGSTON

GROUND FLOOR



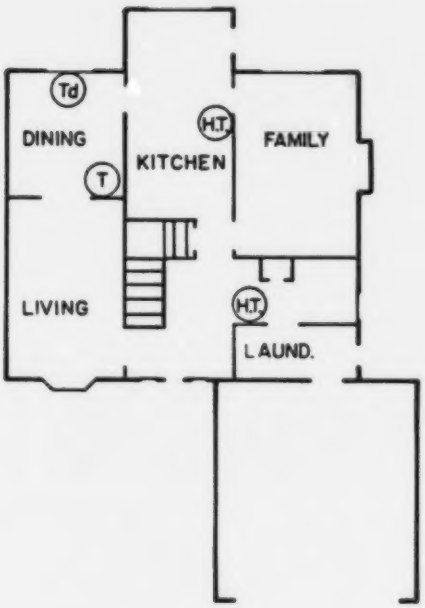
SECOND FLOOR



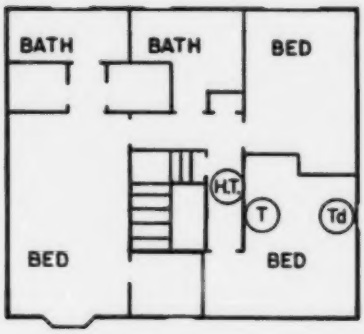
BASEMENT

HOUSE E, KINGSTON

T - Wall Mounted Temperature Sensor
Td - Duct Mounted Temperature Sensor
HT - Wall Mounted Humidity/Temperature Sensor

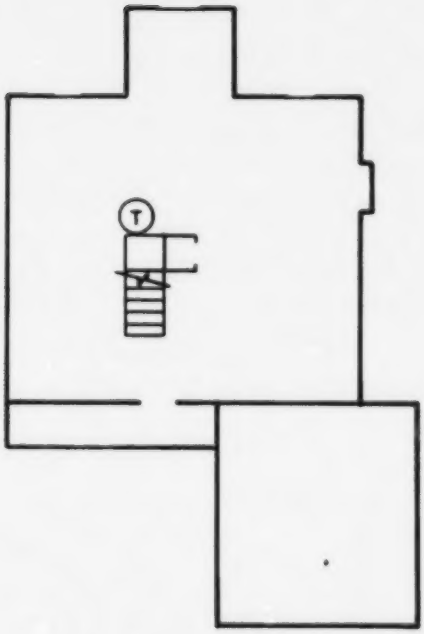


GROUND FLOOR



SECOND FLOOR

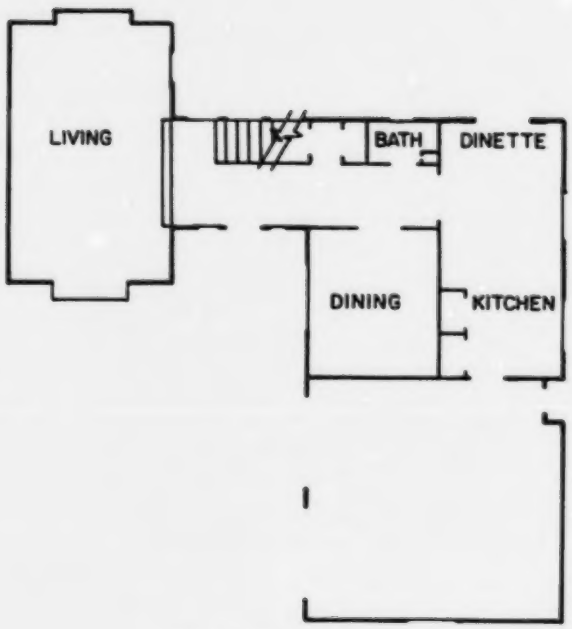
0 5 METRES



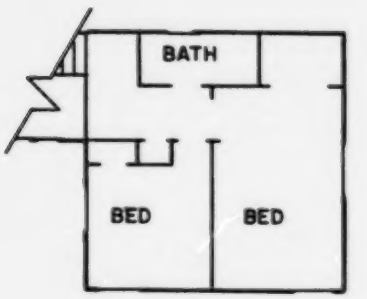
BASEMENT

HOUSE A, FONTHILL

T - Wall Mounted Temperature Sensor
Td - Duct Mounted Temperature Sensor
HT - Wall Mounted Humidity/Temperature Sensor



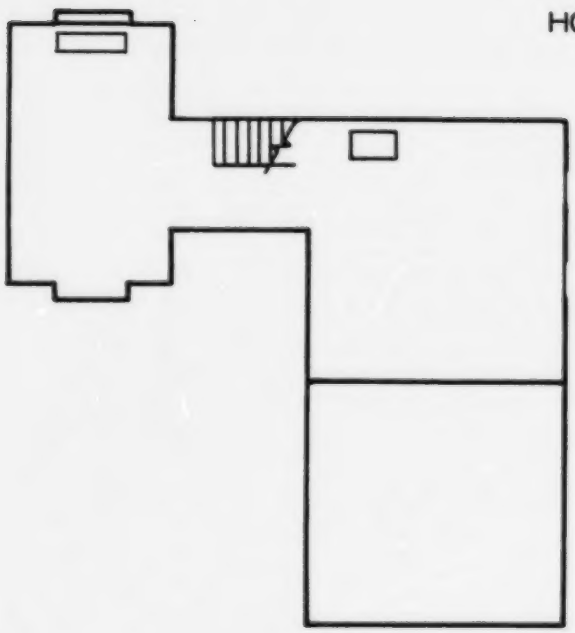
GROUND FLOOR



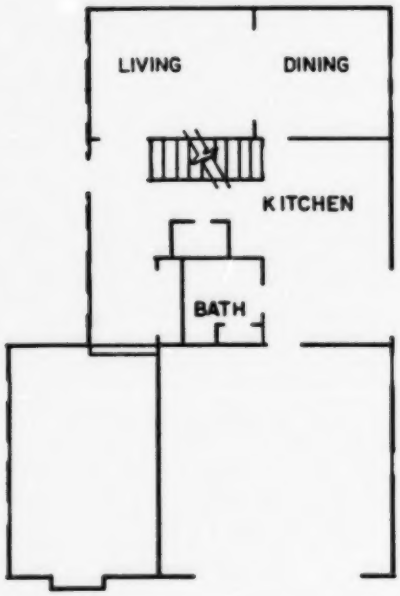
SECOND FLOOR

0 5 METRES

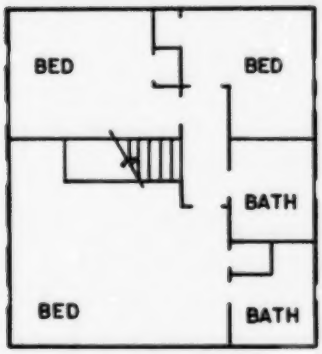
HOUSE B, FONTHILL



BASEMENT

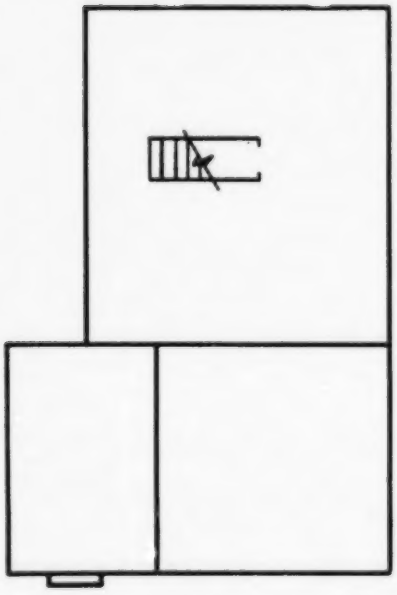


GROUND FLOOR



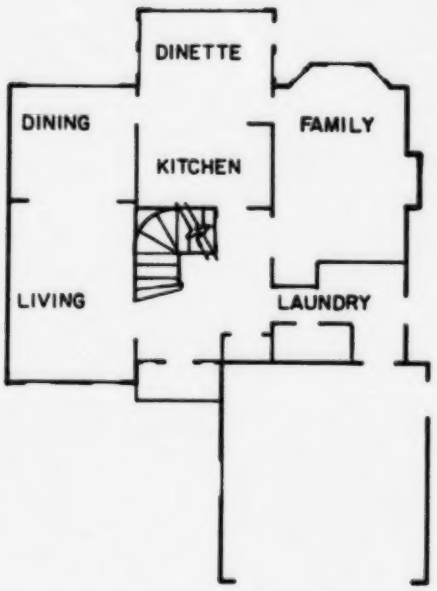
SECOND FLOOR

0 5 METRES

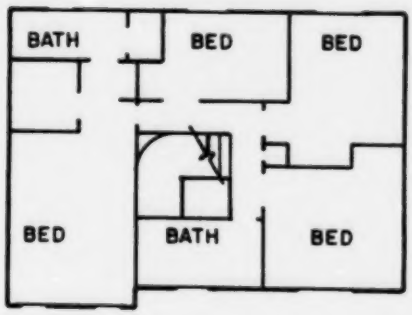


BASEMENT

HOUSE C, FONTHILL

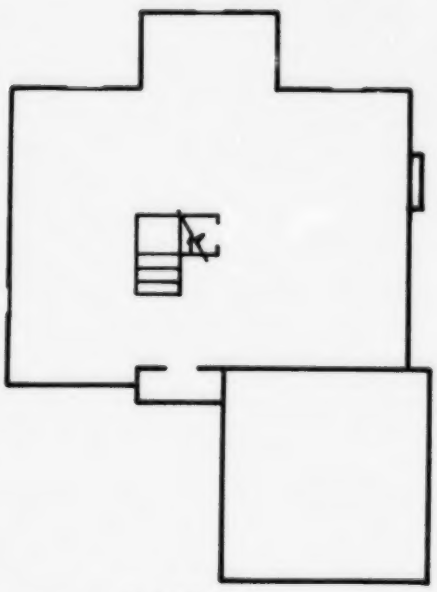


GROUND FLOOR



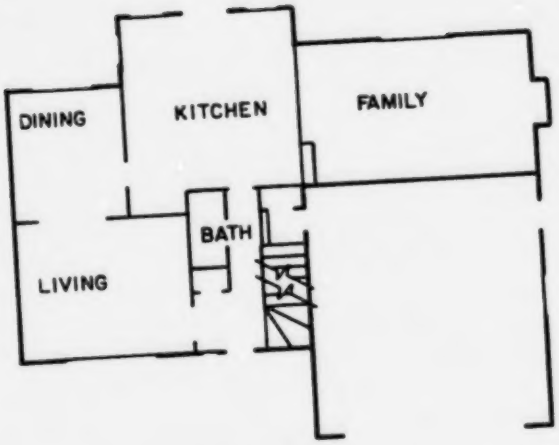
SECOND FLOOR

0 5 METRES

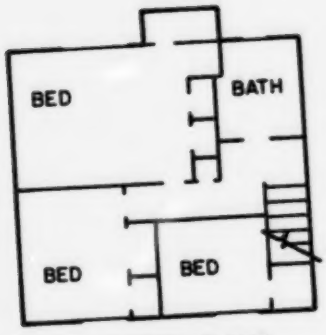


BASEMENT

HOUSE D, FONTHILL

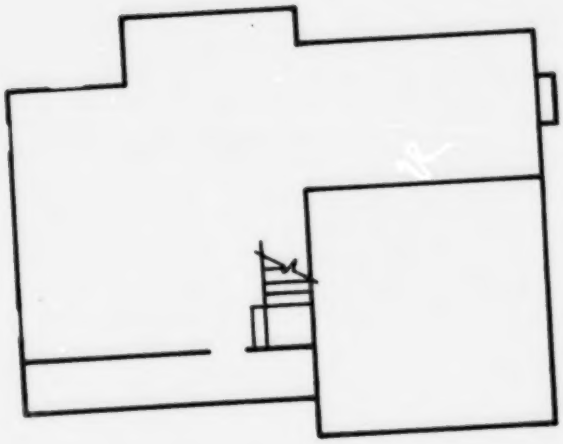


GROUND FLOOR



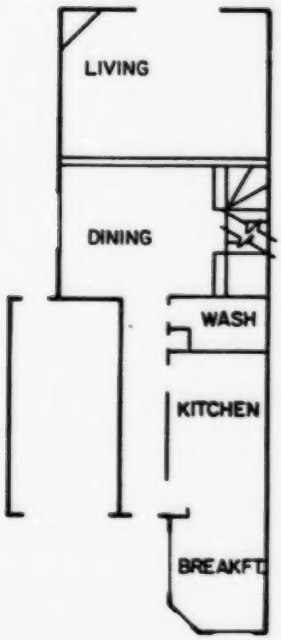
SECOND FLOOR

0 5 METRES

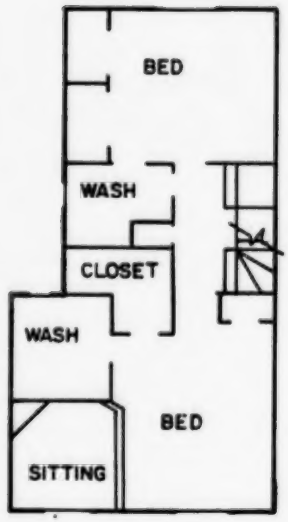


BASMENT

HOUSE E, FONTHILL

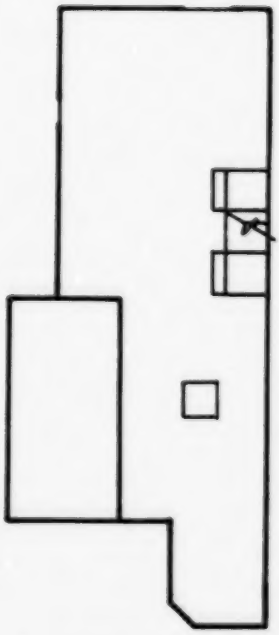


GROUND FLOOR



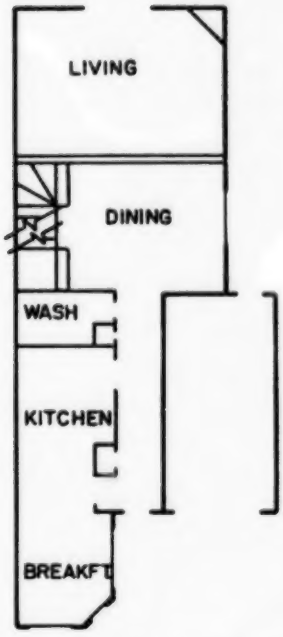
SECOND FLOOR

0 5 METRES

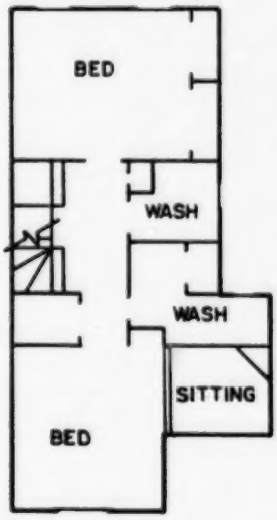


BASEMENT

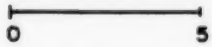
HOUSE A, ERIN MILLS

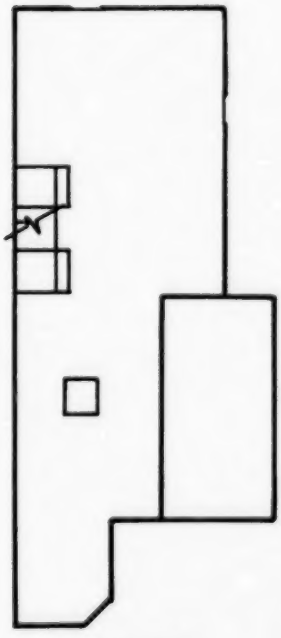


GROUND FLOOR



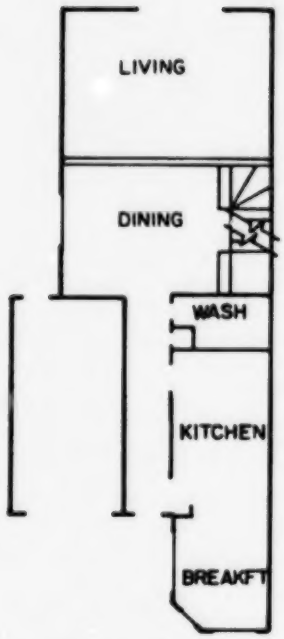
SECOND FLOOR



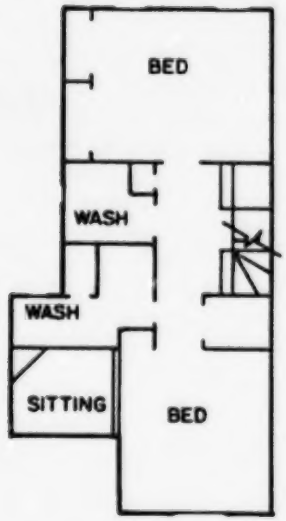


BASEMENT

HOUSE B, ERIN MILLS

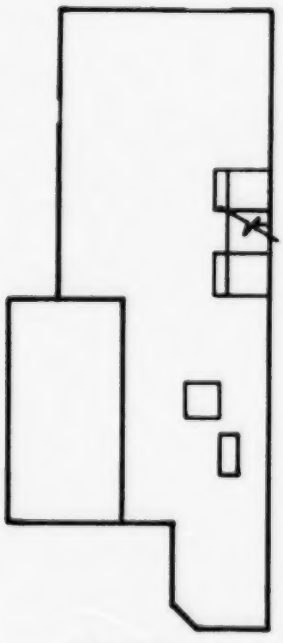


GROUND FLOOR



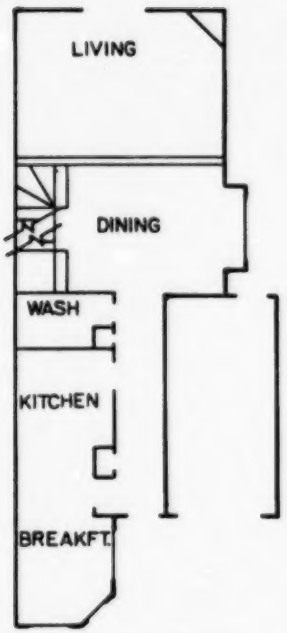
SECOND FLOOR

0 5 METRES

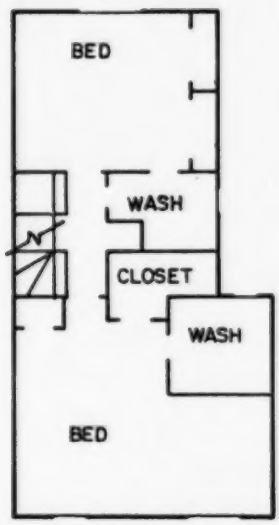


BASEMENT

HOUSE C, ERIN MILLS

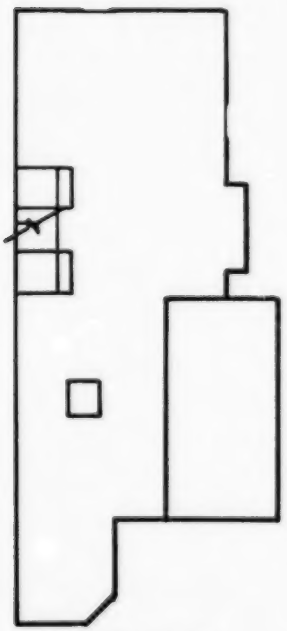


GROUND FLOOR



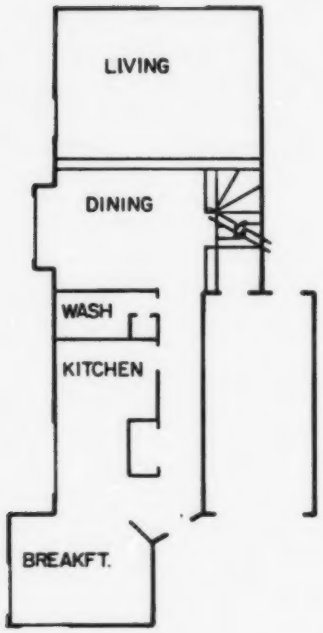
SECOND FLOOR

0 5 METRES

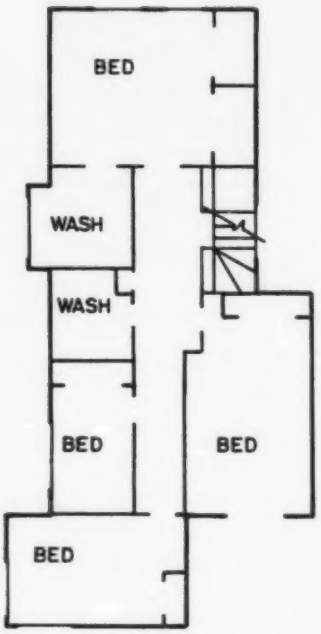


BASEMENT

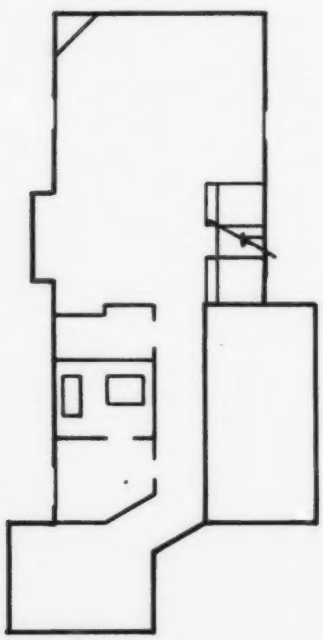
HOUSE D, ERIN MILLS



GROUND FLOOR

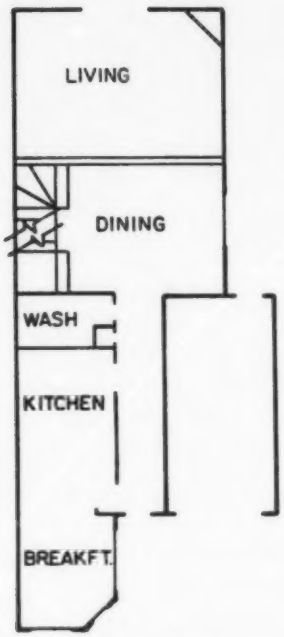


SECOND FLOOR

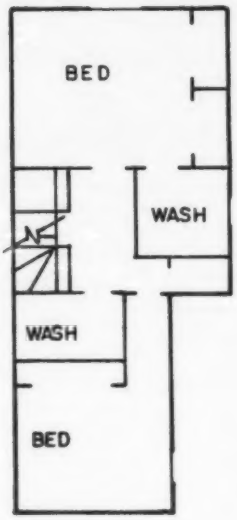


BASEMENT

HOUSE E, 'ERIN MILLS

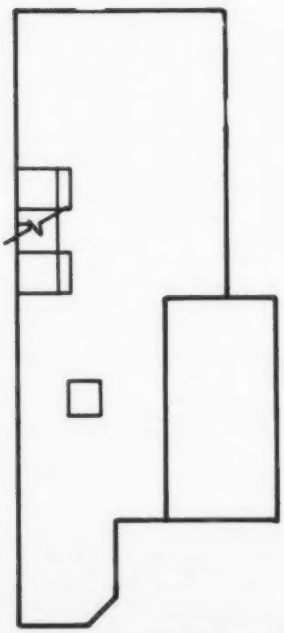


GROUND FLOOR



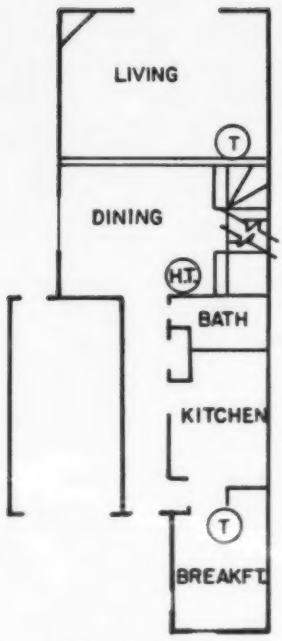
SECOND FLOOR

0 5 METRES

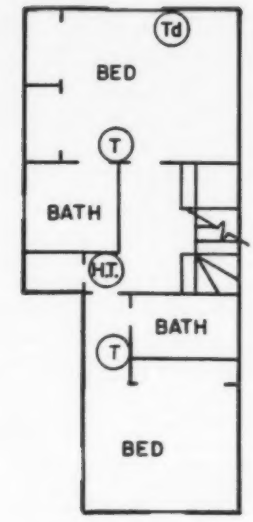


BASEMENT

HOUSE F, ERIN MILLS

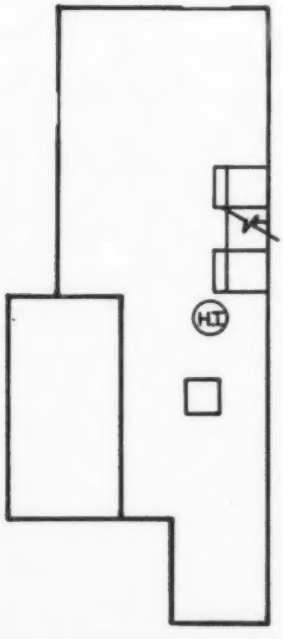


GROUND FLOOR



SECOND FLOOR

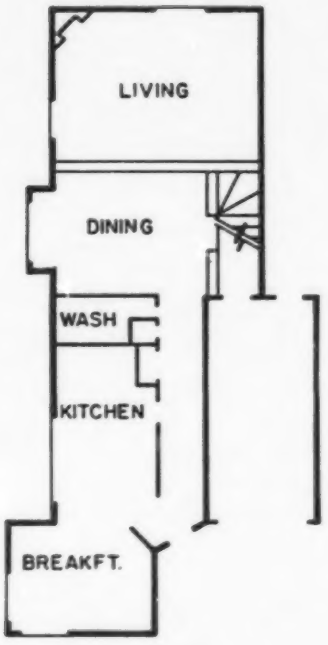
0 5 METRES



BASEMENT

HOUSE G, ERIN MILLS

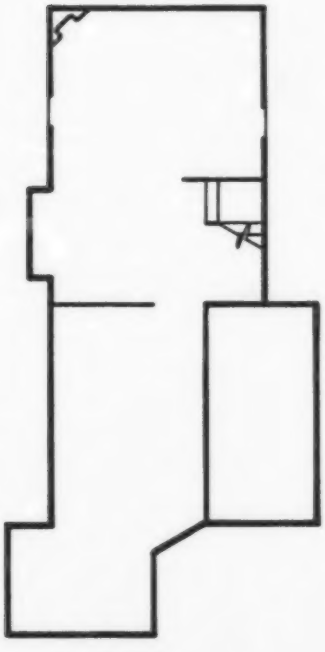
T - Wall Mounted Temperature Sensor
Td - Duct Mounted Temperature Sensor
HT - Wall Mounted Humidity/Temperature Sensor



GROUND FLOOR

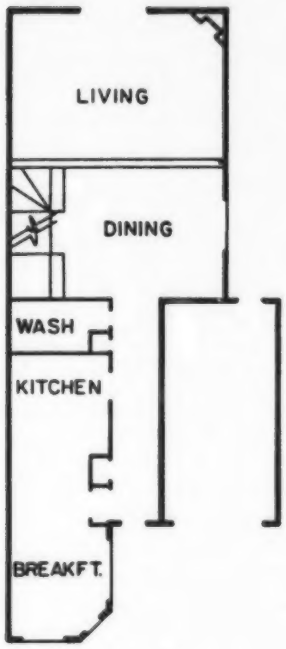
SECOND FLOOR

0 5 METRES

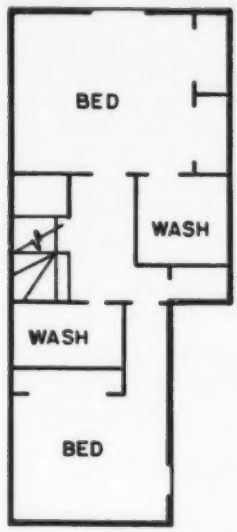


BASEMENT

HOUSE H, ERIN MILLS

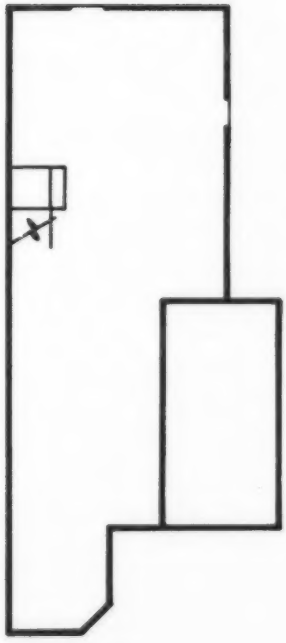


GROUND FLOOR



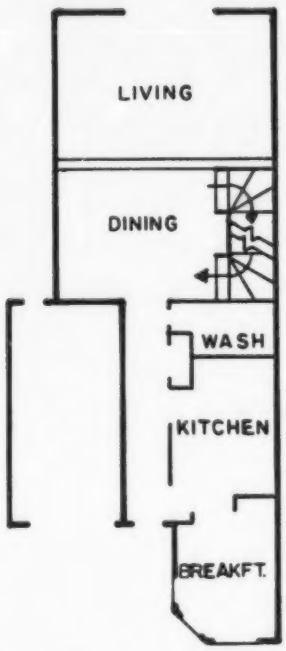
SECOND FLOOR

0 5 METRES



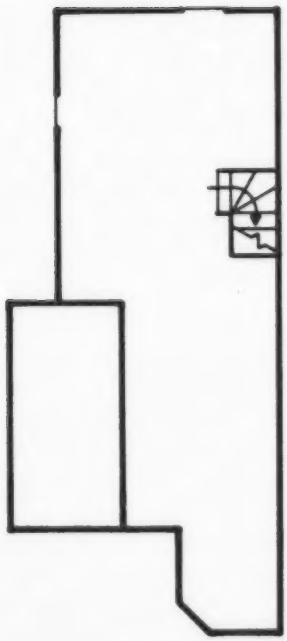
BASEMENT

HOUSE 1, ERIN MILLS



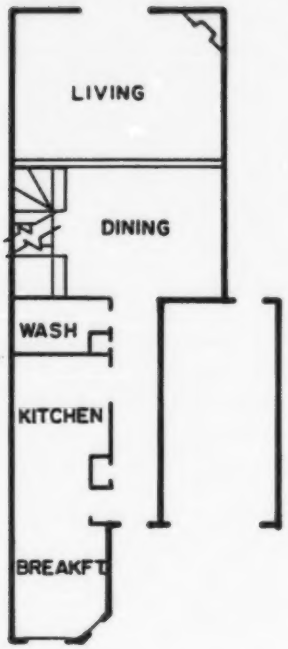
GROUND FLOOR

SECOND FLOOR

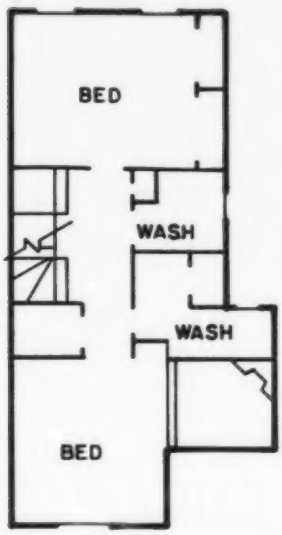


BASEMENT

HOUSE J, ERIN MILLS



GROUND FLOOR



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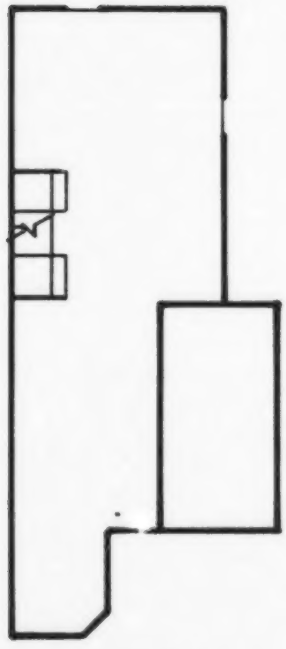
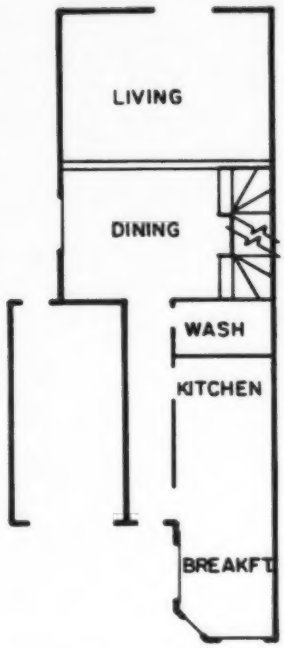
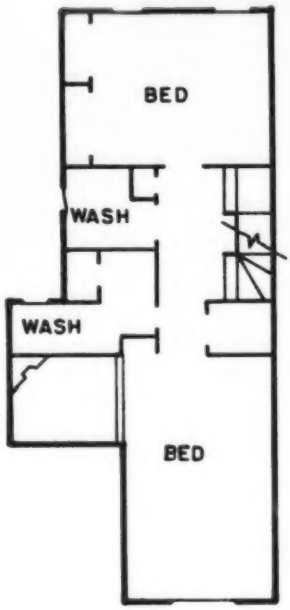


BASEMENT

HOUSE K, ERIN MILLS



GROUND FLOOR



SECOND FLOOR

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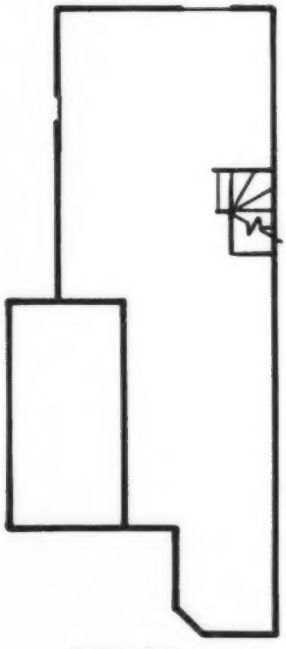

BASEMENT

HOUSE L, ERIN MILLS